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MELVILLE T. COOK, Editor

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OBSERVATIONS ON SOME INSECTS ASSOCIATED WITH SUGARCANE IN PUERTO RICO

By F. M. WADLEY,
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In connection with investigations carried on by the Bureau of Entomology and Plant Quarantine in Puerto Rico with special funds from August 1935 to June 1936 to obtain information on insects which transmit sugarcane diseases, surveys were made to secure data on the status and distribution of the insects in and around sugarcane fields, with special reference to those forms which feed on the juices of plants. The work was headquartered at the Federal Experiment Station at Mayagüez, which cooperated by supplying laboratory and other facilities and giving helpful suggestions and advice. This paper reports results of these surveys.

The sugarcane insects of Puerto Rico were listed by D. L. Van Dine (**10**) in 1913, with a review of earlier work. This list was supplemented by later observations on cane insects made by Jones (**4**, **5**), Smyth (**9**), Wolcott (**12**), and Seín (**7**). Wolcott has published a general list of Puerto Rican insects (**15**) and a textbook including chapters on cane insects of the West Indies (**14**). The cane insects of Santo Domingo have been listed by Wolcott (**13**) and those of Cuba by Van Dine (**11**). Insects in relation to cane mosaic in Puerto Rico have been discussed by several writers, especially Smyth (**8**). Chardon and Veve (**1**), and Seín (**6**).

In the present survey the greatest attention was paid to those sucking insects which might conceivably transmit mosaic disease. Three species were noted as occurring regularly on cane, viz, the yellow cane aphid, *Sipha flava* Forbes; the mealybugs, mostly *Trionymus sacchari* Ckll.; and the fulgorid *Saccharosydne saccharivora* Westw. Three additional aphids were carefully observed because these were occasionally found on cane or because they were suspected of transmitting mosaic disease. These were *Aphis maidis* Fitch, *Hysteroneura setariae* Thos., and *Carolinaia cyperi* Ainslie. Other

insects were observed incidentally, and observations were made on grasses which harbor some of these insects.

A few ecological details may be recorded for the benefit of those not familiar with Puerto Rico. The climate is tropical. The rainy season sets in late in the spring in most sections, reaches its height late in the summer or early in the fall, and declines late in the fall. The winter and early spring months comprise the dry season. This year (1935–1936) the drought was unusually pronounced, and the rainy season began suddenly at Mayagüez about May 1 with heavy and frequent rains. The north coast shows a moderate rainfall, 50 to 60 inches a year in many places. The interior mountains and the east, west, and northeast coasts have a high rainfall, 80 inches or more. The south coast has a comparatively low rainfall, 40 inches or less, and here cane is produced under irrigation. Nearly all the sugarcane is grown on the coastal plain or in valleys reaching toward the interior, practically none occurring in the central mountains. Some of the areas of most intensive cane culture are located in the southern irrigated part. The cane is harvested from January to May.

Two systematic extensive surveys of the cane-growing areas of the island were made, one in the fall of 1935, the other in the spring of 1936, the localities examined being indicated on the map (fig. 1). Other field observations were made occasionally, and an intensive survey was conducted at the experiment station at Mayagüez each month that other work permitted.

The Intensive Survey

The intensive survey at the experiment station included examination of cane varieties, grasses, and sedge. Six cane varieties, of some commercial importance, were growing in large replicated plats, and these were observed regularly; these were POJ 2878, M 28, M 63, FC 916, PR 803, and PR 807. Some small areas of old and new varieties were also available. Various grasses, *Panicum barbinode, Syntherisma, Capriola, Echinochloa colonum, Eleusine indica, Andropogon virgatus* (tent. det.), and *Cyperus rotundus* (a sedge), were common not only at Mayagüez but all over the island; while some other grasses occur but are less common. Corn is found growing at the experiment station at most times of the year. Over most of the island it is grown in small fields in either spring or fall. A small plot of sorghum grew at the experiment station, but this species is rare on the island.

The most noteworthy results of this survey are shown in table I.

TABLE I. RESULTS OF INTENSIVE SURVEY OF SUGARCANE INSECTS AT THE EXPERIMENT STATION AT MAYAGUEZ, P. R. 1935-36

Insect	Plant	Percentage infested in month of—								
		August	Nov.	Dec.	Jan.	Feb.	March	April	May	June
Aphis maidis	Corn, tasseled	some	26	26	14	15	20	8	40	.....
	Sorghum	some	82	54	58	26	48	16	52	66
	Panicum barbinode, field	few	1-	3	1-	0	1	0	1	.....
	Panicum barbinode, moist ditch	.....	.....	.....	.....	8	8	6	2	.....
	Echinochloa colonum	.....	3	4	0	0	0	0	8	.....
	Sugarcane	very few	0	0	0	0	0	0	1-	0
Hysteroneura setariae	*Eleusine indica*	few	4	7	12	8	8	19	3	0
	Panicum barbinode	.....	0	1	6	1	8	1	5	.....
	Syntherisma	.....	0	6	4	11	2	3	0	.....
	Echinochloa colonum	.....	2	8	4	8	2	0	0	.....
	Sugarcane	0	0	0	0	0	1-	0	1-	0
Sipha flava	Sugarcane	many	8	6	14	15	34	65	57	11
	Chaetochloa setosa	.....	18	10	10	4	16	22	12	.....
	Syntherisma	.....	1	0	1	1	4	2	5	.....
Carolinaia cyperi	*Cyperus rotundus*	.....	25	10	28	21	1	1-	0	0
Saccharosydne saccharivora	Sugarcane	few	1	1-	1-	2	1-	1-	1-	0
Mealybugs	Sugarcane	some	10	27	35	43	some	some	12	.....
	Sorghum	.....	42	74	70	(cut)	some	40	36	.....

(In most cases the stalk or stem was the unit counted; in the cases of *Eleusine* and *Cyperus* the whole plant was the unit taken. Most of the percentages for sugarcane represent several hundred units; from 50 to 100 samples of other plants were examined.)

The results of the survey on a number of cane varieties were recorded separately, but these details are omitted for the sake of brevity. Only a few varietal differences were encountered. The cane variety POJ 2878 had heavier mealybug infestations than other varieties, PR 803 showed somewhat greater populations of *Sipha flava* than others, and the unimportant variety M 505 was outstandingly susceptible to *Sipha flava.*

Mosaic disease was not an important factor around Mayagüez, since nearly all cane grown there was of highly resistant varieties. The few small areas of susceptible varieties seen were considerably infected, and mosaic-like symptoms were noted on crabgrass and sorghum. Sugarcane borers (*Diatraea* sp.) were present at all times, but onty in moderate numbers; the variety PR 807 was most consistently infested.

Mealybugs (*Trionymus sacchari*) seemed rather scarce on young cane, and were difficult to find without uprooting the plants. On older cane they were more numerous and located higher on the plants, under the sheaths. Dead mealybugs covered with fungus were sometimes seen, especially in rainy weather. *T. sacchari* was also found on sorghum. Another mealybug, *Pseudococcus brevipes* Ckll., was seen occasionally on crowns of *Panicum barbinode, Eleusine indica* and *Cyperus,* and once on corn. Root insects were not included in the survey.

In addition to these records, *Aphis maidis* was seen occasionally on untasseled corn, a few times on *Coix lachryma-jobi, Pennisetum purpureum,* and *Gynerium sagittatum,* and once on *Chaetochloa setosa* and *Cyperus.* Only migrants of this aphid were seen on cane in the field, though at one time a colony occurred in a cage. The species was usually found on heads or terminals of plants, but sometimes on the leaves. It was found in greater numbers in cages or sheltered places than in the open. When numerous, *A. maidis* was attacked by parasites and predators. Parasites reared included *Lysiphlebus testaceipes* Cress., *Pachyneuron siphonophorae* Ashm., and *Tetrastichus marylandensis* Gir. Predators included coccinellids and syrphids.

Hysteroneura setariae was found in small numbers a few times on *Paspalum conjugatum, P. paniculatum* (tent. det.), *Capriola dactylon, Panicum reptans* (tent. det.), *Andropogon virgatus* (tent. det.). *Sporobolus virginicus* (tent. det.), and *Gynerium sagittatum.* It was nearly always found on the heads of grasses, although sometimes stems or leaves were colonized, especially on *Eleu-*

sine. Colonies occurred on cane (on the auricle) in southern Puerto Rico, but not at Mayagüez. When abundant, this aphid was attacked by parasites, predators, and under damp conditions by a fungus (*Acrostalagmus aphidum* Oud.) Parasites reared included *Lysiphlebus testaceipes, Pachyneuron siphonophorae,* and *Aphidensyrtus aphidivorus* Mayr.

Sipha flava occurred on the leaves of its food plants, a reddish discoloration being associated with its feeding. Besides the plants noted in table I it was found a few times on *Panicum barbinode, P. maximum, Eleusine indica, Echinochloa colonum, Paspalum conjugatum,* and *P. paniculatum* (tent. det.), and one migrant was observed on corn. The species occurred on grasses in small numbers, but sometimes became numerous and injurious on sugarcane, 400 individuals once having been found on a single leaf. It was attacked by predators and a fungus (*Acrostalagmus*), but parasites were not seen in this work. Predators observed were a few syrphids and some coccinellids, including *Cycloneda Sanguinea* L. and a small black species.

Carolinaia cyperi was seen only on *Cyperus,* usually in small numbers, and no insect enemies were observed. *Saccharosydne saccharivora* was usually seen only on cane, but was once swept from grass, mostly *Panicum barbinode.*

Numerous other insects were encountered. Several aphid migrants, not yet determined, occurred on cane in May; some seemed to be from nearby citrus. Leafhoppers and fulgorids were frequently found on cane and grasses, but seemed in most cases to be transients. *Cicadella similis* Walker on *Panicum barbinode* and other grasses, *Delphacodes* sp. on *Echinochloa colonum, Peregrinus maidis* Ashm. on corn, and *Phaciocephalus cubanus* Myers on cane were especially noted. *Nesostelus incisus* Mats. was swept from grass, mostly *P. barbinode; Typhlocybella minima* Bak. and *Empoasca* sp. were swept from *Bradburya;* and *Empoasca* from indigo. Chinch bugs (*Blissus leucopterus* var. *insularis* Barber) occurred on grasses a few times. Ants, principally the fire ant, attended aphids, and were especially active around mealybugs. Snout beetles, caterpillars, scales, psocids, thrips, mites, and other organisms were noted in small numbers. *Chirotrips mexicanus* Crawf. was repeatedly noted in heads of *Eleusine indica.*

Aphids were determined by P. W. Mason, mealybugs by Harold Morrison, aphid parasites by A. B. Gahan, leafhoppers and fulgorids by P. W. Oman and H. L. Dozier, thrips by J. C. Crawford, and the fungus by Vera K. Charles.

The Extensive Survey

The first extensive survey was conducted in September and October 1935, late in the rainy season. The cane at this time was of medium to large growth. A field was selected at random in each of the 34 localities marked on the map (fig. 1). In each field 100 stalks were examined in 5 samples of 20 each, well distributed through the field. The results appear in Table II.

Insects were found much as recorded for the intensive survey. The borer *Diatraea saccharalis* F. was widespead and often injurious; it seemed somewhat more numerous in the south than elsewhere. *Hysteroneura setariae* occurred on *Eleusine* near Aguadilla, Río Grande, Naguabo, Fajardo, Patillas, and on *Gynerium* at Guánica. *Aphis maidis* occurred in small numbers on *Panicum barbinode* near Isabela, Guayama, Naguabo, Fajardo; on *Gynerium* at Guánica; on corn near Loíza, Fajardo, Hatillo, Arecibo, Naguabo, Dorado, Isabela, and Juana Díaz; and on *Pennisetum* (elephant grass) near San Germán. *Sipha flava* was recorded once on corn, once on crabgrass, and once on an unknown grass.

The second extensive survey was conducted in March and April 1936, toward the end of an unusually severe dry season. Some fields were still unharvested, with stalks of large growth and dry lower leaves (classes as "large" in Table III). Some were fall-planted, of medium growth (rather large when irrigated, as in the south). Some were of new ratoon growth and rather small. Sampling was conducted as in the fall survey and approximately the same localities were selected, except that the one in San Sebastián and one in Cabo Rojo were omitted. The results appear in Table III.

Other insects were noted much as in the fall survey and the intensive survey. *Diatraea saccharalis* was widespread and somewhat injurious in places. It was more abundant in southern Puerto Rico and less abundant on the west coast than elsewhere. Little difference in its numbers could be noted between varieties or seasons. Chinch bugs were found once on a single stalk of cane at Humacao.

Aphids found on nearby plants included *Aphis maidis* on corn at San Germán and on *Panicum barbinode* at Guánica, Caguas, and Guayama. *Hysteroneura setariae* occurred on *Eleusine* at Carolina, Yabucoa, Guayama, Santa Isabel, and San Lorenzo; and on *P. barbinode* at Rincón, Arecibo, and Yabucoa. *Carolinaia* occurred on *Cyperus rotundus* near Arecibo, Dorado, Ponce, Peñuelas, Yauco, and San Lorenzo.

TABLE II. RESULTS OF EXTENSIVE FALL SURVEY OF SUGARCANE INSECTS IN PUERTO RICO, 1935

Section	Locality	Variety of cane	Percentage of stalks with—						Aphids on nearby plants
			Mealybug	*Saccharosydne saccharivora*	*Sipha flava*	*Hysteroneura setariae*	*Aphis maidis*	Mosaic	
West coast	Cabo Rojo (1)	POJ 2878	64	10	2	0	0	0	
	Cabo Rojo (2)	M 28	24	13	36	0	0	0	
	Cabo Rojo (3)		41	1	1	0	0	0	
	Mayagüez	POJ 2878	21	11	8	0	0	0	See table I
	Rincón	POJ 2878	17	11	25	0	0	0	
	Aguadilla	POJ 2878	74	6	11	0	0	0	*Hysteroneura setariae*
North coast	Isabela	M 28	19	5	11	0	0	0	*Aphis maidis*
	Hatillo	POJ 2878	47	5	4	0	0	0	*Aphis maidis*
	Arecibo	POJ 2878	32	16	0	0	0	1	*Aphis maidis*
	Manatí	POJ 2878	57	12	17	0	0	0	*Aphis rumicis*
	Dorado	PO. 2878	39	3	1	0	0	1	*Aphis maidis*
	Carolina	SC & BH	20	23	8	0	0	6	
	Río Grande	SC 12-4	46	1	25	0	0	0	*Hysteroneura setariae*
East coast	Fajardo	BH 10-12	40	5	17	0	0	0	*Hysteroneura set.,*
	Naguabo	BH 10-12	29	3	9	0	0	21	*Do. Aphis maidis*
	Humacao	BH 10-12	24	13	28	0	0	0	
	Yabucoa	BH 10-12	4	7	11	0	0	1	
South coast	Guánica	BH 10 12	15	4	16	6	0	0	*Hysteroneura setariae,*
	Peñuelas	BH 10-12	20	5	4	0	0	0	*Sipha flava,*
	Ponce	BH 10-12	6	1	34	4	0	1	*Aphis maidis*
	Santa Isabel	BH 10-12	54	11	3	0	0	3	
	Guayama	BH 10-12	17	4	0	6	0	0	*Aphis maidis*
	Patillas	BH 10-12	32	4	18	0	0	0	*Hysteroneura setariae*
Interior valleys	San Sebastián	POJ 2878	47	12	2	0	0	0	
	Añasco	PO. 2878	24	1	5	0	0	0	
	Quebradillas	POJ 2878	45	17	9	0	0	1	
	Barceloneta	POJ 2878	18	4	19	0	0	1	
	Caguas	SC 12-4	55	9	9	0	0	37	
	San Lorenzo	SC 12-4	59	12	4	1	0	37	
	Loíza	BH 10-12	15	2	15	0	0	6	*Aphis maidis*
	Juana Díaz	BH 10-12	37	5	38	0	1	0	*Aphis maidis, Sipha*
	San Germán	POJ 2878	43	14	23	0	0	0	*Aphis maidis flava*
	Yauco	BH 10-12	60	0	7	0	0	1	
	Lajas	BH 10-12	66	1	0	0	0	0	

TABLE III. RESULTS OF EXTENSIVE SPRING SURVEY OF SUGARCANE INSECTS IN PUERTO RICO, 1936

Section	Locality	Variety of cane	Growth	Percentage of stalks with—						Aphids on nearby plants
				Mealybug	*Saccharosydne saccharivora*	*Sipha flava*	*Hysteroneura setariae*	*Aphis maidis*	Mosaic	
West coast	Cabo Rojo (1)	POJ 2878	Small	0	0	31	0	0	0	
	Cabo Rojo (2)	POJ 2878	Small	16	3	29	0	0	0	
	Mayagüez	POJ 2878	Medium	22	8	64	0	0	0	See table I
	Rincón	M 28	Medium	25	2	37	0	0	0	*Hysteroneura setariae*
	Aguadilla	M 28	Medium	5	5	5	0	0	0	
North coast	Isabela	M 28	Small	0	2	4	0	0	0	
	Hatillo	M 28	Small	6	1	2	0	0	0	
	Arecibo	BH 10-12	Medium	16	2	33	0	0	6	*Hysteroneura setariae,*
	Manatí	M 28	Small	1	56	42	0	0	0	*Carolinaia*
	Dorado	M 28	Medium	15	3	5	0	0	1	*Carolinaia*
	Carolina	SC 12-4	Large	41	0	11	0	0	4	*Hysteroneura setariae*
	Río Grande	POJ 2878	Large	91	0	8	0	0	0	
East coast	Fajardo	BH 10-12	Medium	11	1	1	0	0	0	
	Naguabo	BH 10-12	Small	6	1	12	0	0	0	
	Humacao	BH 10-12	Medium	31	2	18	0	0	0	
	Yabucoa	BH 10-12	Medium	8	0	0	0	0	0	*Hysteroneura setariae*
South coast	Guánica	BH 10-12	Medium	32	1	0	0	0	0	*Aphis maidis*
	Peñuelas	BH 10-12	Medium	2	2	37	3	0	30	*Carolinaia*
	Ponce	BH 10-12	Medium	7	4	22	0	0	0	*Carolinaia*
	Santa Isabel	BH 10-12	Medium	4	1	8	0	0	0	*Hysteroneura setariae*
	Guayama	BH 10-12	Medium	0	1	40	0	0	0	*Hysteroneura setariae,*
	Patillas	BH 10-12	Medium	39	4	17	0	0	3	*Aphis maidis*
Interior valleys	Añasco	POJ 2878	Large	70	2	8	0	0	0	
	Quebradillas	M 28	Large	65	5	19	0	0	0	
	Barceloneta	FC 916	Medium	14	21	19	0	0	0	
	Caguas	POJ 2878	Small	0	1	22	0	0	0	*Aphis maidis*
	Loíza	BH 10-12	Medium	4	1	5	0	0	20	
	San Lorenzo	POJ 2878	Large	73	1	4	0	0	0	*Hysteroneura setariae,*
	Juana Díaz	POJ 2878	Large	93	1	4	0	0	0	*Carolinaia*
	San Germán	SC 12-4	Large	33	1	4	0	0	28	*Aphis maidis*
	Yauco	Co 281	Small	15	0	0	0	0	0	*Carolinaia*
	Lajas	"Jap"	Small	1	0	0	0	0	0	

Discussion

Mealybugs, often in large numbers, were found wherever search was made on cane. Wet weather appears to be unfavorable to them. The mealybugs are hard to find on young, small cane, but they seem to be come very abundant on cane that is old and has nearly stopped growing. Hence they are numerous in unharvested fields in the dry season. They were somewhat more numerous on POJ 2878 than on other varieties. While these insects do not receive much consideration, they may cause more injury than is generally suspected. Their work is not conspicuous.

Sipha flava was also widespread, and in the spring was somewhat more numerous in western Puerto Rico than in other parts of the island. It became more abundant in dry weather, but wet weather was not unfavorable enough to keep it from maintaining numerous small colonies. It became locally injurious near Cabo Rojo following a short dry spell in August 1935 and was somewhat injurious over wide areas in the spring of 1936. It seemed to favor certain varieties, but little preference was shown among the more important ones. It appears to be among the minor problems of cane growing.

Saccharosydne saccharivora was widely present, but nearly always in small numbers. In the fall it was less abundant in the dry south-coast country than elsewhere, and in the spring it was generally less abundant than in the fall. Thus on the whole it seems that dry conditions were not favorable; but in the one field, where it was very abundant, dry conditions prevailed (Table III, Manatí). It did not appear to do much injury.

Aphis maidis was more abundant in the rainy than in the dry season. This may be ascribed to the better condition of the food plants. It was seldom found on cane. It was present on some grasses in widely scattered localities, but only in small numbers. Sorghum is a favorable but rare host. The only host that supported large populations over any considerable area was tasseled corn. According to observations of Mr. B. A. App and the writer, *Aphis maidis* occurred on corn all over the island, but corn was not abundant in the areas of the south and east coasts, where cane is grown as the almost exclusive crop. Corn was found growing close to cane most often in areas of diversified farming.

Hysteroneura setariae occurred in small to moderate numbers on grasses all over Puerto Rico, and in limited numbers on cane (BII 10–12) along the south coast. It was rarely seen on cane elsewhere

The colonies on cane were on the auricles, as has been observed in Louisiana. It was not seen on BH 10–12 in sections other than the south coast, and was once observed in the southern region in a field of SC 12–4. Hence the difference in distribution seems to be regional rather than varietal and may be ascribed to low rainfall and the favorable growth of irrigated cane. The species was much more abundant in dry than in rainy weather.

Carolinaia cyperi was found in a number of places in small or moderate numbers, and was seen only on the common sedge, *Cyperus rotundus*. It was more abundant in dry than in rainy weather, except when its food plant was injured by drought. It persisted at some points in the dry region in May, after rains had set in at Mayagüez and it could no longer be found there.

Tables II and III show the susceptibilty of the cane varieties SC 12–4 and BH 10–12 to mosaic, and its almost complete absence in other important varieties. The resistant varieties have almost entirely replaced the susceptible ones in the west, and have largely replaced them on the north coast and in interior valleys. In the south and east BH 10–12 is still widely planted. Jensen (**3**) finds that the spread of mosaic disease is rapid in the west, north, and interior and slower in the south. He observes that it is more rapid near hills and pastures and less rapid near the sea and in areas solidly planted to cane. In the areas of rapid spread, fields of susceptible varieties are often heavily infected, though control by roguing sometimes gives fair results. In areas of slow spread control by roguing is usually successful, though infected fields occur.

The areas of slow or rapid spread must be marked by scarcity or abundance of vectors, respectively. Mealybugs are numerous in both areas, and hence do not seem likely to be a vector; the same is true, to an extent, of *Saccharosydne saccharivora*. The yellow aphid *Sipha flava* also occurs throughout the island and experiments in transmission with this aphid under this project have been negative. In the same experiments *Hysteroneura setariae* and *Carolinaia cyperi* have shown ability to transmit mosaic. It is doubtful whether they are of much importance in field transmission, because they are at least as numerous in areas of slow spread as in areas of rapid spread. *Aphis maidis* seems more likely to be important in field transmission, because of the evidences mentioned of its greater abundance in the areas of rapid mosaic spread in the west, north, and interior than in the areas of slow spread. Another possibility in field transmission is that aphids having no association with grasses might trans-

mit mosaic by temporary feeding on cane in the course of migration. A situation of this sort was found in connection with a disease of onion (Drake, Harris, and Tate (**2**)). Such aphids have been taken on cane at Mayagüez, and in one case positive transmission was secured with a species not normally found on grasses. Rapid mosaic spread shows a strong association with diversified plant growth, which is probably accompanied by an abundance of vectors.

Summary

Survey work in 1935–36 on sugarcane insects of Puerto Rico, especially those which may transmit mosaic disease, is described. Previous work is cited; climate, geography, and methods are outlined briefly.

Aphis maidis was found to be rather abundant on tasseled corn, sparingly present on several grasses, and scarce on cane. *Hysteroneura setariae* was moderately abundant on some grasses, occasional on cane along the south coast, and rare on cane elsewhere. *Sipha flava* was widespread on cane, sometimes injurious, and small numbers occurred on grasses. *Carolinaia cyperi* was found in moderate numbers on a sedge. *A. maidis* was most numerous in the rainy season, the other three in the dry season. Mealybugs were numerous, especially on mature cane. *Saccharosydne saccharivora* was widespread but seldom numerous on cane. Some minor insect notes are recorded.

Aphis maidis seems likely to be important in mosaic dissemination, because more abundant in areas of rapid than of slow spread. *Hysteronera* and *Carolinaia* seem less likely to be important, and the other insects named seem unlikely to be implicated at all. Some aphids not breeding on grasses may be important.

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NOTES ON THE CHANGA, OR WEST INDIAN MOLE CRICKET, IN PUERTO RICO IN 1935 AND 1936

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INTRODUCTION

A study of the changa (*Scapteriscus vicinus* Scudd.) was conducted in Puerto Rico in 1935 and 1936 by the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, in cooperation with the Puerto Rico Agricultural Experiment Station at Mayagüez. During this period changa damage was apparently not so severe as it has been in the past, according to the observations of previous workers. This was perhaps partly due to the severe drought which extended over practically the entire Island during part of this period, for although this drought occurred during the normal dry season it exceeded in severity those of all previous Weather Bureau records covering a period of 25 years. Under such conditions changa damage is normally much less severe.

Sugarcane comprises approximately 35 percent of the entire marketable crops produced on the Island and a much larger proportion of the crops susceptible to changa damage. Although repeated observations were made in the sugarcane fields over the entire Island, however, in only a few instances was any appreciable changa damage noted. Damage to coffee, the second largest crop, was limited to a few slight infestations occurring in seedling beds. Tobacco, ranking third as an economic crop, is considered one of the favorite host plants of the changa, but there was no important damage to this crop, and the heaviest infestation was that observed in a small field of approximately three-fourths of an acre in which 10 percent of the plants had been destroyed. The only cases of severe damage were confined to minor crops such as sweet corn and vegetables, several cases having been observed in which from 50 to 98 percent of the crop was destroyed. In practically all of these cases, however, the planting did not exceed 1 acre and the resulting commercial loss was therefore relatively slight.

A part of the popular belief existing on the Island concerning the seriousness of the changa problem is doubtless due to the fact

that a considerable amount of damage caused by other insects is attributed to the changa. Damage by white grubs and cutworms is often confused with changa damage, and cases have come to the writer's attention in which chinch bugs, millipedes, and even fungus diseases, were causing the reputed changa injury.

Distribution

Distribution limited to definite areas of the Island.—One of the main purposes of this project was to determine the limits of distribution of the changa on the Island. This was accomplished by making extensive surveys over practically the entire area. This insect was found to occur in the following localities: Aguirre, Añasco, Arecibo, Arroyo, Bejuco, Cabo Rojo, Caguas, Carolina, Cayey, Corozal, Florida, Guayama, Hormigueros, Humacao, Isabela, Lajas, Las Marías, Loíza, Maleza Baja, Maricao, Mayagüez, Pueblo Viejo, Río Piedras, Quebradillas, and Yabucoa. Since practically all of these points are around the coast or within the interior river valleys, the observations indicate that the distribution of this insect is limited to such areas. Other workers on the changa in Puerto Rico have reached similar conclusions.

Type of soil the chief factor limiting distribution.—Such factors as elevation, temperature, and distribution of host plants appear to have little or no effect on distribution. Abundance of rainfall seems to be of some importance, there being apparently more changas in the areas receiving the greatest amounts of precipitation. The chief factor limiting distribution is undoubtedly the type of soil. Distribution is quite definitely limited to light-textured, sandy soils. These soils are particularly adapted to the burrowng activities of the changa and thus afford the most suitable environment. In heavy clay soils, the insect is either very rare or entirely absent. Unfortunately, soils best suited to the growing of vegetables and similar crops are the only soils inhabited to any great extent by the changa; consequently damage to such crops is particularly heavy unless control measures are employed.

Host Plants

The changa feeds upon a wide range of host plants. Feeding has been observed by the writer on the following: Basil (*Ocimum basilicum*), bean, cabbage, coffee seedlings, young cotton plants, cucumber, eggplant, sweetpotato, tobacco, and various grasses. Only plants showing visible evidence of feeding on the stem at the crown were

included in this list. Severe injury is caused in this manner and usually results in the destruction of the plant. Other workers on the Island report the changa as feeding upon the following, in addition to the plants in the foregoing list: Cantaloup, collard, onion, pea, rape, rice, turnip, *Colsus* spp., and *Livingstonia* spp. In fact, almost any young plant may serve as food, although plants having a poisonous or acrid sap are said to be avoided.

The writer's cage studies and field observations have shown that the changa feeds also to a considerable extent on decomposing organic matter in the soil, and it has been found that it feeds upon its own and other species of insects.

Damage

Damage to plants by the changa results mainly from its feeding activities, but some damage results from the uprooting of the seedling plants caused by movements of the changa through the soil. Feeding is confined entirely to the roots and stems, usually at the crown in the latter case. Stems are either completely severed or are so badly gnawed that they are no longer able to support the weight of the plant. Obviously, the greatest amount of damage results from this type of feeding, since injury to the stem usually causes the loss of the entire plant.

The greatest damage normally occurs after heavy rains or after the soil has been moistened by irrigation. This is because the changa is active at the surface only when the soil is sufficiently softened by moisture to permit such activity, and it is at such times that feeding upon stems occurs. Since feeding on the roots of plants produces little appreciable damage, it is apparent that the most injury can take place only under the above conditions. In general, the greatest amount of damage may be expected during the rainy season.

Natural Enemies of the Changa

A number of native birds are known to be of value in preying upon the changa. These have been recorded by Wetmore (U. S. Dept. Agr. Bul. 326, 1916). The more important of these are listed here in the order of their importance:

Martinete, or green Cuban heron	*(Butorides virescens maculatus)*
Falcón, or Puerto Rico sparrow hawk	*(Falco sparverius loquaculus)*
Playero, or Antillean killdeer	*(Oxyechus vociferus rubidus)*
Putilla, or spotted sandpiper	*(Actitis macularia)*

Garza, or little blue heron	*(Florida caerulea)*
Judio, or smooth-billed ani	*(Crotophaga ani)*
Ruiseñor, or Jamaican mocking-bird	*(Mimus polyglottos orpheus)*
Clérigo, or Puerto Rico petchary	*(Tolmarchus taylori)*
Pitirre, or gray kingbird	*(Tyrannus dominicensis dominicensis)*
Juí, or Antillean flycatcher	*(Myiarchus antillarum)*
Garzón blanco, or American egret	*(Casmerodius albus)*

These birds should receive every possible protection.

A few minor enemies, such as ants, spiders, and lizards, have been recorded, but these are relatively unimportant.

Observations have been made which indicate that the giant toad (*Bufo marinus*) is an important enemy of the changa. This animal was first introduced into the Island in 1920 and it appears to have been playing a considerable part in the control of the changa since that time. An examination of the stomachs of a small number of these toads during the latter part of 1935 revealed that the changa comprised about 15 percent of the stomach contents. This, however, is probably not a true indication of the extent to which they are preyed upon by the toad, because, owing to the dry condition of the soil, changas were not very plentiful at the time.

Good Control by Poisoned Baits

Satisfactory control of the changa can be obtained by the use of poisoned baits. The bait formulated by Crossman and Wolcott in 1915 is extensively used on the Island and is fairly efficient. It consists of a mixture of paris green and flour, the proportion of paris green being from 3 to 10 percent of the total mixture. Three percent of paris green is usually sufficient.

The bait should be broadcast over the field at the rate of 300 pounds per acre about one week before planting. This should be done as late in the afternoon as possible, preferably after a rain, since the best results are obtained when the surface of the soil is wet. In cases of severe infestation a second application may be necessary, and this also should be made prior to planting, since it is very difficult to apply this bait broadcast in a field containing growing plants and avoid burning them. The bait may also be applied around individual plants. In this case, shallow trenches are first made around each plant and a small quantity of bait is placed around the bottom of each trench. Applications of this type require only about

150 pounds of bait per acre, but all other conditions mentioned above should be observed.

Some work was completed which indicated that the substitution of wheat bran for flour increased the efficiency of the bait. This should first be mixed thoroughly with the paris green and then the mixture should be moistened with water until a handful of the mixture will no longer fall apart or break up after being compressed, but not enough water should be added so that any moisture can be extracted in this way. Applications can be made in the same manner as described above.

Other Methods of Chemical Control of Some Value

It was found that a mixture of 8 ounces of pyrethrum powder to 2 gallons of water, when poured over the surface of the soil, kills the changas immediately below the surface. This method of control should be used only when the soil is wet; and since the cost of the material is high, its use is restricted to special cases where the cost is justifiable.

A strong solution of blue soap (the common laundry soap obtainable anywhere on the Island) and water when used as above is of considerable effectiveness. This mixture should be poured into individual burrows if possible. It should be applied at an early hour in the morning when the changas are near the surface in the fresh burrows made the preceding night. All changes driven to the surface may be readily collected and killed. With this treatment killing is necessary since the action of the soap and water renders the mole crickets inactive for only a short time.

Summary

Distribution of the changa is limited to the coast and to the interior river valleys of the Island. Type of soil is the chief factor limiting distribution.

A wide variety of host plants are attacked, but a slight preference appears to be shown for certain plants.

The main damage results from feeding, which is confined to the roots and stems of plants. The greatest damage occurs when the surface of the soil is wet.

Few, if any, important natural enemies of the changa, other than birds, are native to the island, although the introduced giant toad seems to be proving a valuable aid in control.

Poisoned baits afford a satisfactory means of control, and other means of chemical control may be employed.

DESCRIPTIONS OF MISCELLANEOUS CHALCIDOID PARASITES FROM PUERTO RICO. (HYMENOPTERA)

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During the course of recent entomological investigations in Puerto Rico advantage was taken of the opportunity to collect for study certain groups of small chalcid wasps. The present paper gives descriptions of thirteen new species from Puerto Rico, together with three additional species from other localities. Rearing records of four previously described but little known encyrtids are also given. Most of the parasites treated in this paper are either coccid-inhabiting or parasitic in the eggs of other insects. One is an important larval parasite of the Cuban laurel thrips, *Gynaikothrips uzeli* (Zimm.).

FAMILY ENCYRTIDAE

Leptomastidea antillicola, new species

Easily distinguished from all described members of the genus by the difference in wing markings and male genitalia.

Male.—Length, exclusive of oedeagus, 1.075 mm., expanse 2.137 mm., greatest width of forewing 0.358 mm.

General color yellowish, the head and prescutum a soiled orange, the pronotum fuscous; the scutellum, metanotum, propodeum, and abdomen embrowned. Eyes greenish. Antennae brown, the scape paler along inner margin at base. Forewings hyaline, with the marginal vein and the stigma brown, and a short, prominent, oblique brown vitta extending from the marginal vein basally but not reaching the posterior margin; an irregular fuscous clouding extending across the apex and following around the posterior margin for over half its length. Legs a soiled testaceous, the posterior ones distinctly darker.

Head slightly narrower than the thorax. Frontovertex appearing polygonally reticulate under high magnification. Eyes prominent, distinctly hairy. Antennae slightly longer than the body, the scape and pedicel reticulated; the scape slightly compressed, almost four times as long as wide, greatest width at the middle; pedicel short, only a fourth as long as the scape, narrowed at base; funicle with verticillate whorls of long cilia, joints 3–6 provided with inconspicuous longitudinal sensoria; first funicle joint slightly longer than the others, but distinctly shorter than the club. Pronotum very short. Prescutum rather short, nearly two and a half times as wide as long, covered with numerous

black setae. Scutellum triangular, rounded at apex, provided with strong setae, and appearing scaly reticulate under high magnification. Forewings comparatively broad, measuring 0.860 mm. in length by 0.359 mm. in width, densely ciliate except for a somewhat oval and oblique bare area beneath the marginal vein. Abdomen subovate, slightly longer than the thorax. Male genitalia long and slender, without lateral process; claspers with a pair of short, small spines.

Female.—Unknown.

Type.—Cat. No. 51762, U. S. National Museum.

Described from a single male reared by Dr. M. R. Smith from *Pseudococcus virgatus* on foliage of "Guaba", *Inga inga*, in coffee grove of the University of Puerto Rico Demonstration Farm at San Sebastián, P. R., May 12, 1936.

Anagyrus similis, new species

In general appearance and antennal coloration this species is close to *Anagyrus coccidivorus* Dozier and *A. subalbipes* Ishii but is differentiated from those at once by its black head, pronotum, and prescutum.

Female.—Length 1.46–1.58 mm., expanse 2.27–2.44 mm., greatest width of forewing 0.35–0.37 mm. Head opaque black; pronotum and prescutum black, the remainder of the thorax a soiled orange. Antennae white, the basal half of the pedicel and the entire first funicle joint black and the scape black, marked with a conspicuous pale area occupying the distal fourth, this pale area yellowish on the dorsal half and clear transparent on the ventral half. Abdomen light brown; the legs a soiled testaceous-yellow.

Eyes covered with numerous short, erect, dark, setae. Mandibles bidentate, the lower tooth smaller. Antennae very long and slender, 0.90 mm. in length, covered with numerous short hairs, the scape conspicuously widened or foliaceous, twice as long as greatest width, covered with numerous strong setae, particularly prominent over the pale distal area; funicle joints distinctly longer than wide, funicle 1 the longest funicle joint and subequal to the pedicel in length; funicles 2–4 subequal in length and very slightly longer than funicles 5 and 6. Forewings 1.00 mm. in length and 0.37 mm. in width, rather uniformly ciliated except the oblique hairless streak. Abdomen distinctly longer than the thorax, narrowed to the tip, the ovipositor hidden.

Male.—Unknown.

Type.—Cat. No. 51742, U. S. National Museum.

Described from the type female taken by the writer sweeping roadside grass and vegetation at Santa Isabel, P. R., Aug. 16, 1935; a paratype female taken sweeping grass on dry pastured slopes near San Germán, P. R., November 26, 1935; and a paratype female taken sweeping "grama" grass, *Paspalum* sp., at Lake Guánica, P. R., June 30, 1936. The type female and paratype female from San Germán, P. R., are deposited in the U. S. National Museum.

Anagyrus graminicolens, new species

A species easily recognized by its long, prominently protruded, dark ovipositor, and very conspicuous black and white antennae.

Female.—Length, including ovipositor, 2.15 mm., expanse 2.75 mm., greatest width of forewing 0.372 mm. General color a soiled brownish-orange, the head black, the pronotum and mesoscutum black, the scutellum distinctly orange; antennae black except the conspicuously white distal third of the pedicel, second and sixth funicle joints, and entire club; the scape deep black with a transverse conspicuous clear white area near its tip; legs soiled yellowish-orange, ovipositor sheaths black.

Rather elongate in general appearance owing to the very long, prominently protruded ovipositor, the well-tapered abdomen, and the long, slender antennae. Eyes with rather sparse, short, pale setae. Antennae very long and slender, 1.06 mm. in length, covered with numerous short hairs; the scape conspicuously dilated below or foliaceous, three times as long as greatest width, with three very strong setae present at edge of the transparent clear area; first funicle distinctly the longest funicle joint, nearly twice as long as the pedicel; funicle 2 very slightly longer than funicles 3, 4, and 5, which are subequal in length and width; funicle 6 slightly shorter and wider. Darker portions of the body appearing under high magnification in balsam mounts to be minutely but distinctly reticulate. Forewings 1.15 mm. in length and 0.372 mm. in width, rather uniformly ciliated except for the oblique hairless streak. Both thorax and abdomen rather elongate, the latter about a third longer than the thorax, tapered to the prominently protruded ovipositor, which extends for a length of about 0.33 mm. beyond the tip of the abdomen.

Male.—Unknown.

Type.—Cat. No. 51743, U. S. National Museum.

Described from the type female taken by writer sweeping grass and low weeds in beach association, Mani Beach, P. R., August 11, 1935, and a series of 47 paratype females taken sweeping "grama" grass, *Paspalum* sp., in open pasture at Lake Guánica, June 30, 1936. Type female and two paratype females, mounted in balsam on individual slides, together with six paratype females preserved dry and sixteen paratype females in alcohol, are deposited in the U. S. National Museum. The species will undoubtedly prove to be a primary parasite of a grass-feeding mealybug, when its biology is known.

Homalopoda cristata Howard

Howard, Journ. Linn. Soc. London, Zool., 25, p. 91, 1894.

This species was originally described from a single female from St. Vincent. A female, reared by the writer from *Ceroplastes giganteus* Dozier on *Ficus rubricosta* at Source *Cazeau*, Haiti, Dec. 11, 1930, was compared with the type in the National Museum and

proved to be identical. A single female was taken by the writer sweeping at sides of drainage ditch in a sugarcane field at Guayama, P. R., Jan. 17, 1936, and two females were taken on a leaf of a roadside shrub at Mayagüez, P. R., Jan. 23, 1936.

Pseudhomalopoda prima Girault

Girault, Journ. N. Y. Ent. Soc., 23, pp. 171–172, Sept. 1915.

A female was reared by the writer from *Chrysomphalus aonidum* on palm at Damien, Haiti, April 25, 1930, and compared with the type in the National Museum. A second female specimen was reared from *Terminalia catappa* foliage infested with *Aspidiotus destructor* and *Saisettia oleae* at Port-au-Prince, Haiti, Dec. 13, 1929. Dr. Giuseppe Russo reared a female from *Chrysomphalus aonidum* at Moca, República Dominicana, Dec. 12, 1926. The writer reared a female from lemon foliage infested with *Chrysomphalus aonidum* and *Lepidosaphes beckii* at Mayagüez, P. R., Sept. 28, 1935.

Anicetus annulatus Timberlake

Timberlake, Proc. Haw. Ent. Soc., 4, no. 1, p. 277, 1919.

A single female of this species was reared by the writer from "Petit calecon", *Bauhinia divaricata*, material at Source Cazeau, Haiti, Dec. 8, 1930. A female is at hand, reared by Dr. Giuseppe Russo from *Lecanium* scale on rose at Santo Domingo, República Dominicana, April 30, 1927. It has been reared in California and Japan from *Coccus hesperidum* and *Coccus pseudomagnoliarum*. It was definitely shown to be a primary parasite by Harold Compere in 1924.

Metaphycus monticolens, new species

Recognized immediately by its very distinctive orange and fuscous coloration, with distinct metallic reflections.

Female.—Length 0.932–1.00 mm., expanse 1.85 mm., greatest width of forewing .0257–.0272 mm.

Head and pronotum black with slight bluish metallic reflections, practically the entire prescutum dark but a shade lighter and with distinct greenish metallic reflections; remainder of thorax a beautiful contrasting orange, and abdomen fuscous with aeneous reflections. Antennae a soiled testaceous orange, basal two-thirds of pedicel infuscated. Legs pale yellowish; middle femora at their distal fourth and proximal fourth of middle tibiae annulated with fuscous; hind femora slightly infuscated at tip. Forewings hyaline, with a distinctive irregular cross band of light brown occupyng the area of the marginal and stigmal veins, and beneath same following the oblique hairless area to the posterior margin,

where the cloud enlarges and extends distally along the margin for a short distance.

Eyes almost hairless, with a few transparent setae barely visible under highest magnification. Antennae rather slender, the scape flattened on the underside but not expanded, long and slender, five times as long as wide; pedicel somewhat pyriform, distinctly narrowed at base, longer than the first three funicle joints combined; first and second funicle joints subequal in length and width, slightly longer than the third; funicles 4, 5, and 6 increasing gradually in width and length; club as long as the entire funicle combined, twice as long as wide, obliquely truncate. Pronotum opaque, mesoscutum short, covered with numerous setae which break off easily in mounting, and six more prominent ones along near the posterior margin; axillae with five setae each; scutellum under high magnification appearing elongately reticulated, provided with twenty strong setae. Forewings nearly three times as long as wide, measuring .076 mm. in length by .027 mm. in width; postmarginal vein rudimentary; marginal vein much shorter than the submarginal, the latter with four strong marginal bristles; uniformly ciliate distad of the oblique hairless streak. Abdomen shorter than the thorax, somewhat subtriangular in outline, the ovipositor slightly, if at all, protruded.

Male.—Unknown.

Type.—Cat. No. 51761, U. S. National Museum.

Described from the type female, collected by the writer sweeping shrubbery at 3.000 ft., Maricao, P. R., August 18, 1935 and a paratype female taken by the writer on a "guama", *Inga laurina*, tree in a coffee grove in the mountains above Mayagüez, P. R., August 21, 1935.

Hunterellus hookeri Howard

Howard, Canadian Entomologist, 40, pp–239–241, 1908.

Collections of the brown dog tick, *Rhipicephalus sanguineus* Latr., made at irregular intervals at Mayagüez, P. R., from Sept. 24 to November 4, 1935, on a police dog showed a very heavy percentage of parasitization. Parasites issued in numbers on Oct. 23d., and from 10 isolated swollen ticks a total of 77 parasites issued from Nov. 1–4. In every case the parasites issued from second-stage females, each body showing an exit hole towards the posterior end from which one or more parasites issued. Apparently the adult females and males are not attacked. The host tick became much less abundant during November and this could be accounted for by the activity of *Hunterellus hookeri*. More parasites were reared on November 30 from the few ticks collected Two ticks collected on December 2d yielded 16 parasites and a tick collected on December 13th yielded 4 parasites on January 3d. The latter part of December saw a decided increase in the tick again.

Family EULOPHIDAE

Subfamily Aphelininae

Hispaniella howardi, new species

This species might easily be confused with *Aspidiotiphagus citrinus* Howard but is distinguished at once by having only four tarsal joints and broader forewings. A rather short and robust species, very distinct from the European *Hispaniella lauri* (Mercet).

Female.—Length, including ovipositor 0.35–0.40 mm., expanse 0.817 mm., greatest width of forewing 0.086 mm. General color yellowish, the sides of the thorax, base of abdomen, and sides along the middle marked with fuscous; anterior margin of prescutum and pronotum infuscated along the middle; antennae uniformly dusky; legs pale.

Head as wide as thorax, the eyes large and prominent. Antennae 8–jointed, somewhat flattened, the scape long and slender; pedicel distinctly wider than the scape and about one-third as long; first funicle joint decidedly the smallest joint, about half as wide as the pedicel; funicles 1, 2, and 3 increasing in width and length successively; club 3–jointed, the second joint the broadest, slightly longer than the first, and subequal in length to the rather pointed terminal joint; microscopic longitudinal sensoria present on last funicle joint and club. Eyes hairless. Ocelli placed in an equilateral triangle, red. Under high magnification the prescutum and scutellum appear to be faintly and coarsely reticulated. Forewings rather broad, the outer anterior margin well rounded; marginal vein furnished with five distinct marginal setae; the submarginal vein always with a single small inconspicuous seta; disk with numerous, fairly uniformly arranged, short setae, a bare area about the stigma; marginal fringe of cilia very long, those on posterior margin distinctly longer than those on the anterior margin, the longest equaling the width of the wings. Forewings hyaline except for a clouded area which extends across the entire width of the wing behind the marginal vein; marginal vein dusky. Abdomen much longer than the thorax but distinctly narrower; the ovipositor slightly exserted. All tarsi 4–jointed.

Male.—Unknown.

Type.—Cat. No. 51685, U. S. National Museum.

Described from a series of twenty six females mounted in balsam, and which were reared by the writer from *Parlatoria pergandii camelliae* Comstock (det. Harold Morrison), on Croton foliage at Port-au-Prince, Haiti, April 13–May 6, 1931. The type female on a slide with a single paratype female, and eight paratype females on two slides, are deposited in the U. S. National Museum.

Named in honor of Dr. L. O. Howard, who did so much excellent pioneer work on scale parasites.

Prospaltella pulchella, new species

An unusually beautiful species. Nearest to *P. murtfeldtii* (Howard) but differing at once in the extent of clouding of the forewings and by having the first funicle joint silvery white instead of brown. Also closely allied to *P. fasciativentris* Girault but the anterior femora are not annulated with dusky nor is the abdomen shining piceous as in that species which also has funicle 1 distinctly brown and funicle 2 more dusky than 3.

Female.—Length, including ovipositor, 0.731 mm., expanse 1.305 mm., greatest width of forewing 0.20 mm. General ground color light yellowish; the thorax somewhat varicolored, in general brownish, the sides lighter, the pronotum, metanotum and propodeum distinctly fuscous. Antennae with the scape and pedicel slightly dusky, all three funicle joints silvery-white; the first two club joints dark brown, the terminal joint white, slightly dusky towards the base. Vertex dusky yellowish, the ocelli red. Forewings hyaline, with a broad infumation or fuscous cloud extending across the wing beneath the distal half of the marginal vein and reaching beyond the stigmal vein. Abdomen fuscous, the apex, the sides irregularly so, and a broad transverse band across the basal fourth, silvery-white. Legs pale, the middle and hind tibiae each with a single fuscous annulation, the middle femora with an indication of a fuscous clouding on lower margin; first and second tarsal joints of anterior legs brown, the middle and hind tarsi with only first joint brown.

Head transverse, distinctly wider than the thorax, the prominent eyes naked. Antennae fusiform, conical at apex, with distinct longitudinal sensoria; scape long and slender, five times as long as wide, narrower than pedicel; pedicel distinctly wider than first funicle joint and twice as long; the three funicle joints successively shorter and slightly increasing in width, funicle 3 nearly twice as long as funicle 1; club 3-jointed, tapered to conical apex, the first joint distinctly the widest, and slightly longer than the second, the terminal joint the longest, pointed. Under high magnification the prescutum, axillea, and scutellum appear coarsely polygonally reticulate, the areas along median line of scutellum longitudinally elongated; the prescutum with a pair of extra strong lateral setae, and nine smaller ones on each side; the scapulae with three setae each, the axillae each with a single one, and the scutellum with a pair of strong setae on each side. Forewings broad, about two and a half times as long as wide (measuring 0.50 mm. in length by 0.20 mm. in width), marginal vein almost equal in length to the submarginal; stigmal vein very short, its anterior border nearly parallel with the costa, shaped somewhat like the head of a bird; disk of wing rather densely ciliated, the cilia less abundant on basal portion beneath the submarginal vein and a large conspicuous area lying beneath basal half of marginal vein appearing hairless owing to the transparency of the pale cilia at that point. Abdomen somewhat ovate in outline, the ovipositor slightly protruded. Tarsi 5-jointed.

Male.—Unknown.

Type.—Cat. No. 51754, U. S. National Museum.

Described from a single female, reared June 17, 1931, by the writer at Port-au-Prince, Haiti, from a shipment of apple twigs

infested with the wooly apple aphid, collected at Camden, Del., and forwarded by L. L. Williams in connection with the attempted introduction of *Aphelinus mali* (Haldeman) into Haiti. The species is undoubtedly a parasite of some apple-infesting coccid.

This species is a typical *Prospaltella* and is certainly congeneric with the genotype, *Prospaltella murtfeldtii* (Howard), and with *P. fasciativentris* Girault, *P. fasciapennis* Girault, and *P. forbesi* Dozier, all of which have the conically pointed club and the stigma bearing a resemblance in outline to that of a bird's head.

Prospaltella elongata, new species

Easily distinguished by coloration and its comparatively narrow, elongated form, an adaptation apparently to the extremely elongated body of its host scale.

Female.—Length, including ovipositor, 0.50 mm., expanse 1.13 mm., greatest width of forewing 0.158 mm. General coloration yellowish-orange, nearly the apical two-thirds of the abdomen, the ovipositor, the upper portion of the head, the pronotum, and the anterior margin of the prescutum, fuscous; antennae uniformly yellowish-orange; legs pallid.

Head slightly wider than the thorax, the vertex transversely rugulose. Antennae long, somewhat flattened, with longitudinal sensoria, the club distinct but only slightly wider than the funicle; scape long and narrow, about five times as long as wide; pedicel half as long as the scape but distinctly wider than either the scape or funicle; first funicle joint very short, only half as long as the second funicle; funicle joints 2 and 3 subequal in width and length; club 3-jointed, the first and second joints subequal in width and length, the terminal joint nearly a fourth longer and narrowed to apex. Under high magnification the pronotum, prescutum, scutellum, and axillae appear faintly and coarsely reticulated. Prescutum with eight strong setae, the axilla with a single strong seta, and the scutellum with a pair. Forewings rather broad, 0.459 mm. in length and 0.158 mm. in width, well rounded at apex; submarginal vein with a pair of strong setae; marginal vein with eight strong setae along its anterior margin; a broad infumation or clouding extending from beneath the marginal vein and stigma across the width of the forewings. Abdomen distinctly longer and narrower than the thorax, narrowing apically to a well-rounded apex where the ovipositor is prominently protruded or exserted.

Male.—Unknown.

Type.—Cat. No. 51681, U. S. National Museum.

Described from a series of 69 females reared by the writer from the long scale, *Lepidosaphes gloveri* (Packard), on a *Euonymus* shrub in a yard at New Orleans, La., January 6, 1926. The type female and 5 paratype females on one slide, 10 paratype females on a second slide, and 9 paratype females on a third, slide, are deposited in the U. S. National Museum.

This species appears to be a very important parasite and is probably responsible for the fact that the long scale is a minor pest of citrus in the Gulf Coast region, while the purple scale, *Lepidosaphes beckii* (Newman), unchecked by natural enemies, is the most serious enemy of citrus. The writer has observed numerous emergence holes of this parasite in *Lepidosaphes gloveri* at Mobile, Ala.

Encarsia nigricephala, new species

Belongs to the group having the middle tarsi 4-jointed. Distinguished immediately from all other described members of the genus by having the head, pronotum, and anterior two-thirds of the prescutum black. Closely related to *Encarsia cubensis* Gahan but differing in color.

Female.—Length, including ovipositor, 0.46 mm., expanse 1 mm., greatest width of forewing 0.115 mm. General color pale yellowish, contrasting greatly with the black head, pronotum, and anterior discal two-thirds of prescutum; the fuscous portions appearing distinctly reticulate under high power. Head about as wide as thorax, the eyes faintly hairy under high magnification. Prescutum with a single strong seta placed near the margin on each side. Antennae long and slender, testaceous yellow; pedicel almost twice as long as the first funicle and distinctly stouter; first funicle decidedly the shortest antennal joint; funicles 2 and 3 successively slightly longer and subequal in width; funicle 4 slightly longer and wider; terminal joint a third longer than first club joint, widened noticeably at base and then slightly tapered. Forewings rather small (0.40 mm. in length by 0.115 mm. in width), the longest cilia of marginal fringe longer than half the width of the wing; submarginal vein with two setae; wing surface rather sparsely ciliated, the cilia absent from a large bare area embracing the stigmal vein and a border around the outer portion of the wing. Abdomen distinctly shorter than thorax, ovipositor strongly exserted. Legs entirely pallid; all tarsi except those of the middle legs 5-jointed.

Male.—Unknown.

Type.—Cat. No. 51607, U. S. National Museum.

Described from three females reared by the writer from an undescribed whitefly, *Bemisia* sp., abundant on a weed, *Euphorbia hypericifolia,* in a backyard at Mayagüez, P. R., February 12, 1936. These are mounted in damar balsam on individual slides.

Subfamily Tetrastichinae

Tetrastichus tatei, new species

This species could be placed in the genus *Geniocerus* Ratzeburg, following Kourdumoff, as it has more than one bristle on the submarginal vein, but this grouping seems unnatural. Members of the genus *Tetrastichus* Haliday are quite varied in their habits. The

new species is the second described as a definite thrips parasite. *Tetrastichus gentilii* Del Guercio was described as a parasite of *Phloeothrips oleae* in 1911.

Female.—Length about 1–1.16 mm. Dark brown in color, the eyes conspicuously red, with the antennae and legs yellowish-testaceous, and a light or clear median area occuping over a third of the abdomen at its base. This clear area is very characteristic of the species. Antennae 9–jointed including a single minute ring-joint that is visible under high magnification; the three funicle joints subequal in length, the first slightly longer than the pedicel; club slightly wider than funicle, tapered, and only slightly longer than funicle joints 2 and 3 combined. Median furrow on mesoscutum and pair of furrows on scutellum distinct. Forewings hyaline, veins testaceous-yellow; submarginal vein with two very distinct bristles and a less distinct, more posteriorly placed one. Abdomen elongate, almost twice as long as thorax, distinctly petiolate, narrowest at base, the ovipositor nearly concealed.

Male.—Unknown.

Type.—Cat. No. 51608, U. S. National Museum.

Described from numerous females reared by the writer from swollen last-instar nymphs of *Gynaikothrips uzeli* (Zimm.), curling the foliage of Cuban laurel, *Ficus nitida*, on the Experiment Station grounds at Mayagüez, P. R., March 26–April 5, 1936. The Type female mounted in balsam on a slide and paratypes on slides, dry, and in alcohol are deposited in the United States National Museum. Named in honor of H. D. Tate, who called the writer's attention to the damage being occasioned by this thrips.

Family MYMARIDAE

Mymar antillanum, new species

In number of primary marginal cilia this species is closest to *Mymar cincinnati* Girault but differs at once in having the discal ciliation of forewings cephalad of the mid-longitudinal line of cilia.

Female.—Length, including ovipositor, 0.645 mm., expanse 1.749 mm., greatest width of forewing, exclusive of marginal cilia, 0.068 mm. Head, thorax, and abdomen dark brown or fuscous, basal third of abdomen distinctly lighter; pedicel pale; flagellum light brown; legs pale yellowish, slightly embrowned, terminal joint of tarsi distinctly fuscous.

Antennae 9–jointed; scape very long, somewhat curved, swollen at base and apex, four times as long as the short, rather stout pedicel; first funicle only slightly longer and distinctly narrower than pedicel; second funicle by far the longest joint, five times as long as the first, perceptibly enlarged distally; funicles 3, 4, and 5 subequal in length, 6 slightly longer and thicker. The forewing on a very long stalk, the distal portion greatly widened into a distinct blade oar-like; slightly over half of distal part of blade broadly infuscated, line of demarcation very irregular and somewhat oblique; primary marginal cilia 42

in number; discal cilia of the blade mostly cephalad of a mid-longitudinal line which extends from near apex to base of blade. Hind wing reduced to a long, narrow, bristle-like appendage, of which the portion basad of the hooklets is bare, beyond the hooklets for some distance sparsely armed with short setae, the apical one-fourth bare and very slender; the portion beyond the hooklets twice as long as that from base to the hooklets but easily broken off. Abdomen distinctly petiolate, the petiole narrow and about half as long as the abdomen; ovipositor slightly exserted beyond the tip. Legs long and slender, the tarsi 4-jointed.

Type.—Cat. No. 51684, U. S. National Museum.

Described from the type female, collected by the writer sweeping grass and sedges at roadside pond edge near Boquerón, P. R., Sept. 5, 1935; a paratype female taken sweeping grassy path in dense coffee glade at 1,000 ft. in mountains at Las Vegas, P. R., Jan. 2, 1936; a paratype female sweeping low vegetation in an irrigation ditch at the Experiment Station, Mayagüez, P. R., February 28, 1936; and a paratype female taken sweeping grass at swampy edge of roadside, Lake Guánica, P. R., July 13, 1936.

Gonatocerus portoricensis, new species

Closest in general appearance to *Gonatocerus fasciatus* Girault on account of the cross-band on forewing but distinguished at once by its yellowish-orange abdomen, transversely banded with brown.

Female.—Length, including ovipositor 0.774 mm., expanse 1.72 mm., greatest width of forewing 0.222 mm. Head and entire thorax, black; antennae with flagellum dark grayish brown, the scape and pedicel lighter brown; abdomen yellowish-orange in life, fading to a soiled yellowish in balsam mounts, with the tip and four distinct cross-bands or vittae along the anterior margins of segments brown; legs yellowish-brown, the tibiae more deeply infuscated.

Head slightly wider than thorax. Antennae long and rather slender; scape distinctly flattened, three times as long as its greatest width and about twice as long as the pedicel; pedicel narrower than the scape but distinctly wider than the funicle joints, all subequal in length, widening slightly, the first barely perceptibly the shortest; club solid, twice as wide as the last funicle joint and about three times as long. Forewings long, slightly over three times as long as the greatest width; hyaline, the venation and a very distinctive cross fascia near apex of venation brown; rather uniformly ciliated, the ciliated area delimited by a line of cilia which runs from the base of the marginal vein obliquely outward to the posterior margin. Abdomen somewhat ovate, slightly longer than thorax, ovipositor slightly but distinctly exserted; transverse rows of very distinct strong setae arranged along each of the four brown cross vittae and tip in a very characteristic manner.

Male.—Length 0.86 mm. Differs from the female by the long, brown, 13-jointed antennae, distinctly flattened; all joints except the scape and pedicel with longitudinal sensoria; the first funicle slightly the shortest, the others subequal in length and narrowing only slightly, the tip somewhat pointed.

Described from single female specimens collected by the writer in Porto Rico as follows:—Swept from cotton at Isabela, August 1935, sweeping low grass, etc., at roadside, Boquerón, Sept. 5, 1935; sweeping shrubby hillside pasture at 1,000 ft., Mayagüez, Oct. 3, 1935; sweeping hillside weeds in mountains at 1,300 ft., Villalba, Oct. 25, 1935; sweeping bamboo at river edge, Hormigueros, Oct. 31, 1935; swept from pure stand of coffee seedlings in bed near Mayagüez, Nov. 17, 1935; sweeping hillside shrubbery at 1,800 ft., Maricao, Dec. 19, 1935; two females, sweeping grass and weeds at sides of drainage ditch in canal, at Guayama, Jan. 17, 1936; male taken in pasture at Guanajibo, Sept. 11, 1935, and another from roadside weeds at Ensenada, Dec. 5, 1935; a male and a female taken sweeping weeds along Añasco river near Las Marías, July 28, 1936.

Type.—Cat. No. 51678, U. S. National Museum.

Holotype female from cotton at Isabela, P. R., Aug. 19, 1935, allotype male from roadside weeds at Ensenada, Dec. 5, 1935, and the paratype female from Hormigueros, P. R., Oct. 31, 1935 are deposited in the U. S. National Museum collection.

Gonatocerus antillensis, new species

Closest to *Gonatocerus koebelei* Perkins but differentiated immediately by the darker legs and antennal difference.

Female.—Length, including ovipositor, 0.832 mm.; expanse 1.635 mm., greatest width of forewing 0.158 mm. Black, the abdomen narrowly banded with yellow at base, the scape and pedicel a shade lighter than the flagellum in color; legs fuscous.

Antennae rather long, the scape about twice as long as the pedicel, three times as long as wide; funicle joints subequal in length except 5 and 7 which are slightly longer; club solid, equal in length to the last three funicle joints combined. Thorax short and broad, longer than wide. Forewings rather slender, almost five times as long as wide; hyaline, with a very distinct large smoky spot or infumation occupying most of the apical fifth but not quite touching the margins; rather uniformly covered with cilia except a small clear area just distad of stigma, the ciliation terminating towards base at an oblique line running to origin of marginal vein. Abdomen elongate, nearly twice as long as wide, petiolate but petiole very short and inconspicuous; ovipositor distinctly exserted for about a sixth of the abdominal length; ovipositor valves gray.

Male.—Unknown.

Type.—Cat. No. 51679, U. S. National Museum.

Described from the type female, collected by the writer sweeping roadside vegetation at 1,000 ft. near Mayagüez, P. R., Oct. 14, 1935; a paratype female taken sweeping steep roadside slopes, covered with

fern, shrubs, etc., at Miradero, P. R., Sept. 13, 1935; and three paratype females taken sweeping "cohitre", *Commelina longicaulis*, etc., in mountains at 650 ft., Las Vegas, P. R., Dec. 26, 1935.

Erythmelus longicornis, new species

Recognized easily by the unusually long antennae and the pale, dirty yellowish legs.

Female.—Length, exclusive of ovipositor, 0.674 mm., expanse 1.047 mm., greatest width forewing 0.0789 mm. General color fuscous-black, the basal half of the abdomen pale yellowish; antennae grayish-brown, the scape, pedicel, and first funicle barely perceptibly lighter; legs pale, dirty yellowish, front trochanters distinctly pallid, the hind femora darker.

Antennae 9-jointed, unusually long and slender for the genus, the sixth funicle joint distinctly the longest funicle joint, nearly twice as long as the others and distinctly thicker, the scape elongate, subequal to the club in length; pedicel short and stout; funicle 1 distinctly the shortest antennal joint, about half as long as funicle 3, 4, and 5, which are subequal in length; funicle 2 barely but perceptibly shorter than 3, 4, and 5; club solid, only moderately stout, being four times as long as wide. Thorax elongate, slightly shorter than abdomen. Forewings nearly six times as long as greatest width, infumated at base; marginal vein with two prominent setae near anterior margin and two small setae present, placed just distad of the larger prominent ones; distal third of forewing with short discal cilia; marginal cilia along outer posterior margin, longest and a third longer than greatest width of blade. Abdomen somewhat elongate, the pale ovipositor exserted but the hypopygium covers the ovipositor to the apex of the abdomen, as is characteristic for the genus.

Type.—Cat. No. 51755, U. S. National Museum.

Described from a single female taken by the writer sweeping low weeds, etc., in the sandy beach association at Mani Beach, near Mayagüez, P. R., August 11, 1935.

Erythmelus miridiphagus, new species

Closely allied to *Erythmelus longicornis* Dozier but distinguished immediately by the shorter antennae, fuscous legs, and different arrangement of discal setae of forewing.

Female.—Length, exclusive of ovipositor 0.574 mm., expanse 0.932 mm., greatest width of forewing 0.0789 mm. General color black, basal half of abdomen pale yellowish; antenna fuscous, the pedicel a trace lighter; legs for the most part distinctly fuscous, the tibiae, tarsi, and distal tips of femora of front legs pallid; basal third of hind tibiae pallid.

Antennae slightly shorter and stouter than those of *E. longicornis* Dozier, the sixth funicle joint being about twice as long as any other funicle joint; scape four times as long as its greatest width slightly shorter than the club; pedicel short and stout, less than half as long as the scape; first funicle very short, half as long as the second; funicles 2, 3, 4, and 5 subequal in length

and increasing barely perceptibly in width slightly narrower than the 6th; club moderately enlarged, almost five times as long as greatest width. Thorax and abdomen elongate, the latter slightly the longest, with the ovipositor distinctly exserted. Forewings five times as long as their greatest width, slightly infumated at base; marginal vein gray, with two large prominent marginal setae and two smaller ones; distal third of forewing rather sparsely covered with short cilia, with a few inconspicuous ones arranged in an irregular, median line extending basally.

Type.—Cat. No. 51682, U. S. National Museum.

Described from a series of 29 females collected by the writer from a pure stand of *Amaranthus* at edge of cane field at Hormigueros, P. R., Oct. 1, 1935. Enormous numbers of *Polymerus cuneatus* Distant were breeding on this weed and without doubt *E. miridiphagus* is a true egg parasite of this mirid. Heretofore nothing has been recorded in literature as to the hosts of species of *Erythmelus*. Although the species was very abundant at the time, no males could be located. The type female and 10 paratype females, mounted in balsam, are deposited in the U. S. National Museum.

Erythmelus nanus, new species

Most closely allied to *Erythmelus gracilipes* (Girault) of the United States. A small, short, compact species.

Female.—Length, exclusive of ovipositor, 0.573 mm., expanse 0.960 mm., greatest width of forewing 0.086 mm. General coloration, including the antennae, black, the basal third of the abdomen whitish; legs black except the pale yellowish front tibiae and tarsi and the hind trochanters.

Antennae short and stout in comparison with those of other species, the sixth funicle joint only twice as long as wide and subequal to the fourth funicle; scape long, nearly three times as long as the short, stout pedicel; first funicle distinctly the shortest and smallest joint; club stout, nearly three times as long as wide. Thorax and abdomen nearly equal in length and having a more compact appearance than in *E. longicornis* Dozier and *E. miridiphagus* Dozier, and the forewings are broader. Fore and hind wings lightly infumated, slightly paler beneath the marginal vein. Forewings broad, nearly five times as long as wide, the distal fourth with sparse short cilia, arranged in 4–5 lines against the cephalad margin and a line near the posterior margin; marginal cilia very distinct, the longest along the outer posterior margin being just slightly longer than the greatest wing width. Abdomen rather broad, rounded to tip, the ovipositor only slightly exserted.

Type.—Cat. No. 51683, U. S. National Museum.

Described from a type female, collected by the writer sweeping low vegetation along banks of a rocky river at Las Vegas, P. R., Jan. 6, 1936, at 650 ft. elevation in the mountains; and two paratype females taken sweeping low grass and weeds in a pasture at Guanajibo, P. R., Sept. 11, 1935.

Family TRICHOGRAMMIDAE

Oligosita magnifica, new species

Closest to *Oligosita novisanguinea* Girault of Australia but slightly smaller and with the broad basal band of abdomen distinctly yellow instead of white. This species is also closely allied in structure and coloration to the North American *O. sanginea* Girault but distinguished at once by the characteristic yellow band across the base of the abdomen.

Female.—Length, 0.487–0.674 mm., expanse 0.922 mm., greatest width of forewing 0.086 mm. General color a beautiful bright sanguineous or blood red, the base of the abdomen with a broad transverse band of bright yellow covering nearly half its length (this fades greatly in balsam-mounts, legs dusky; antennae concolorous with the legs, the distal two joints slightly darker.

A rather small species. Head about as wide as thorax. Antennae 7-jointed, including a single minute ring-joint; club slender, 3-jointed, at base wider than the funicle joints, narrowed to a point and with a very distinct terminal spine; proximal joint of club distinctly shorter than second or intermediate. Forewings over four times as long as wide, with a very distinct sooty black substigmal spot or suffusion; discal cilia almost entirely absent; marginal cilia longest at the rounded apex, slightly longer than the greatest width of the forewing. Abdomen about a fourth longer than the thorax, robust, narrowed to apex, the ovipositor barely exserted.

Male.—Unknown.

Type.—Cat. No. 51680, U. S. National Museum.

Described from the type female collected by the writer sweeping low grass at edge of Cartagena lagoon, P. R., Nov. 11, 1935; a paratype female taken sweeping sedges and grass at low wet roadside near Boquerón, P. R., Sept. 5, 1935; and a paratype female swept from grass near Bayamón, P. R., June 17, 1936.

THE MOSQUITOES OF PUERTO RICO

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INTRODUCTION

The purpose of this paper is to report the results of mosquito investigations in Puerto Rico during the period July 5, 1935, to June 1, 1936. These investigations were carried on with special funds available to the Bureau of Entomology and Plant Quarantine of the U. S. Department of Agriculture for studies on insects of Puerto Rico. They were under the technical direction of the Division of Insects Affecting Man and Animals, and conducted in cooperation with the Federal Experiment Station at Mayagüez, where headquarters for the investigations were located. Mayagüez is situated in a region of heavy rainfall, and its proximity to the mountainous regions at Maricao and the extremely dry arid region on the southern coast made it a convenient center from which to study mosquitoes under various ecological conditions.

Puerto Rico is a mountainous tropical island. Topographically it consists of a large central mountainous region surrounded by a relatively narrow coastal plain. On the basis of variation of rainfall, the island may be divided in a general way into three regions: (1) the wet coastal plains of the north, east, and west; (2) the dry southern coastal plain, and (3) the central mountainous area, which is subject to heavy rainfall. Practically all of these regions receive their maximum precipitation late in the summer and early in the autumn (August to October) whereas the winter period (December to March) is noticably drier. The average annual temperature along the coastal region is between 75° and 80° F. Because of the influence of the surrounding ocean, seasonal and daily variation in temperature is not pronounced.

PREVIOUS WORK ON THE MOSQUITOES OF PUERTO RICO

In 1922 Root (**22**)[1] reported a list of mosquitoes that he had taken in Puerto Rico together with a summary of all previously reported species. Since that time many new species have been added (Johnson (**13**), Dyar (**2**), Wolcott (**26**)) and the taxonomic status of

[1] The numbers in parenthesis refer to publications given in the bibliography at the end of this paper.

others has been revised (Dyar (**2**)). The following is a list of the species which have hitherto been reported from the island with references to the papers in which the original records appeared; certain doubtful records have been omitted.

Anopheles albimanus Wiedemann (**21**), (**12**), (**25**).
Anopheles grabhamii Theobald (**12**), (**25**).
Anopheles vestitipennis Dyar & Knab (**13**), (**2**).
Megarhinus portoricensis Roeder (**21**).
Aedes sollicitans (Walker) (**26**).
Aedes taeniorhynchus Wiedemann as *A. portoricensis* (**12**).
Aedes mediovittatus (Coquillett) (**24**).
Aedes aegypti (L.) (**12**), (**24**), (**25**).
Psorophora jamaicensis (Theobald) (**12**).
Culex quinquefasciatus Say (**12**), (**24**), (**25**).
Culex secutor Theobald as *C. toweri* (**12**), (**2**).
Culex americanus (Neveu-Lemaire) as *C. bisulcatus* (**12**).
Culex antillum-magnorum Dyar (**2**).
Culex nigripalpus Theobald (**24**) as *C. similis.*
Culex atratus (Theobald) (**22**).
Culex habilitator Dyar & Knab (**26**).
Culex inhibitator Dyar & Knab as *C. borenquini* (**22**), (**2**).
Culex bahamensis Dyar & Knab (**26**).
Deinocerites cancer (Theobald) (**22**).
Uranotaenia sapphirina Ousten-Sacken as *U. socialis* (**22**), (**2**).
Uranotaenia lowii Theobald (**22**).
Mansonia titillans Walker (**26**).
Wyeomyia mitchellii ? Theobald (**26**).
Dixa sp. probably *clavulus* Williston (**26**).
Corethrella spp. probably *appendiculata Grabham* (**26**).

The literature considered in the foregoing paragraphs has been concerned with the taxonomy of mosquitoes. There are many other papers which deal with the habits of mosquitoes and their relationships to such diseases as malaria, filaria, and dengue in Puerto Rico, and these are included along with others of a general nature in the bibliography (**1**, **3**, **4**, **5**, **6**, **7**, **8**, **9**, **10**, **11**, **14**, **15**, **16**, **17**, **18**, **19**, **20**, **21**, **23**).

Economic Importance of the Mosquitoes of Puerto Rico

The geographic position of Puerto Rico is such that climatic factors are favorable for the development of mosquitoes throughout the entire year. The general mosquito problem, therefore, is of

a greater magnitude than that of countries in temperate zones where mosquitoes are active only during a portion of the year. Not only are mosquitoes annoying to man and animals during the entire year, but many of the species transmit the causative organisms of disease.

Mosquitoes are of distinct importance because of the discomfort caused to man and animals by their bites. This is particularly true in the coastal region where the greatest concentration of population is found. The use of bed nets for protection during sleeping hours is a rather general practice, yet there are many people who, because of economic reasons, are unable to avail themselves of this means of protection. The practice of screening houses is not common and consequently practically all of the people are subjected to some degree of annoyance during their waking hours even though many of them are protected during their sleeping hours. Annoyance, then, is a general problem involving a large majority of the people. More important, from a health standpoint, however, are the consequences resulting from the transmission of causative organisms of certain diseases of man by mosquitoes.

One of the most serious health problems which confronts Puerto Rico is malaria. The number of deaths caused by this disease has been between 1,000 and 2,000 annually. Previous to 1924 there were few studies dealing with the incidence of this disease in Puerto Rico. In that year, however, the International Health Board of the Rockefeller Foundation initiated a study to obtain more complete information on all the phases of the malarial problem. The progress of this work has been reported in a series of publications by Earle (**3–10**). Among other things, these studies have indicated that malaria is a serious health problem mainly in the coastal region where the cultivation of sugarcane is the important industry, and that control of the anopheline mosquitoes is practicable in many of the regions where the incidence of malaria is high.

The distribution of filariasis has been studied by Hoffman et al. (**11**). Their studies indicate that this disease is, in the main, limited to the coastal region with Aguadilla on the western coast and parts of San Juan on the northern coast as the most important endemic foci. This disease is not as important as malaria.

Prior to the American occupation of Puerto Rico, yellow fever was a common and, at times, an epidemic disease. Since the American occupation, several cases of this disease have been removed from incoming vessels to the quarantine station by public health officials. The mosquito *Aedes aegypti,* which transmits this disease, is very common in the coastal region of Puerto Rico.

Dengue, although seldom fatal, is a specific fever of warm countries. Frequent cases are reported in Puerto Rico. The nature of the causative organism is not clearly understood, but it is agreed that *Aedes aegypti* is involved in its transmission.

Methods of Collection and Identification

Field collections of larvae were made in all situations in which stagnant or slowly moving waters were present. Most of these collections were made in the western portion of the island but frequent survey trips were made into the eastern portion. The usual situations in which larvae were collected were street gutters and culverts, cisterns and rain barrels, drainage, roadside, and irrigation ditches, swampy areas, and along the margins of ponds, lakes, and rivers. In addition, water was taken from tree holes, crab holes, and the leaf bases of certain plants and examined. The temperature, hydrogen ion concentration, and chlorine content of waters containing larvae were determined by standard field methods. The forms were determined in the larval stage or reared and determined by adult characteristics.

Adults were taken by several methods. In order to determine the relative abundance and distribution of those mosquitoes attacking warm-blooded animals, horse traps were employed. The native horses are small so that a trap seven feet long, five feet high, and 4 feet wide is sufficient for this purpose. The small size of the trap facilities its transfer from one locality to another without difficulty. In addition, the cost of a horse suitable for this purpose is small, which further increases the desirability of the method. The procedure used was to put the horse in the trap late in the afternoon and to collect the trapped mosquitoes just before sunrise the following morning. Collection of adults by light traps was also found useful in determining abundance and distribution of various species, especially certain kinds not usually taken in horse traps. These traps were of the box type, the source of light being a 200-watt clear glass bulb. Other methods for collection of adults were collections in houses to determine the forms that enter dwellings, and net collections in the fields and woods and regions where the use of horse or light traps was impracticable.

The collections from the various sources were examined and the abundance and distribution of the species recorded. The specimens that could not be identified in the field were forwarded to the Division

of Insect Identification for determination. This opportunity is taken to acknowledge, with thanks, the invaluable assistance rendered by Dr. Alan Stone of that division.

Habits, Distribution,[2] and Species of Puerto Rican Mosquitoes

In general, the larval habitats of the various species of mosquitoes in Puerto Rico may be grouped under the following seven type locations:

1. Stagnant water around dwellings.
   (*a*) In cisterns and water barrels—*Aedes aegypti.*
   (*b*) In tin cans, temporary pools, and street gutters (fig. 1) —*Culex quinquefasciatus, Anopheles albimanus,* and occasionally *Culex nigripalpus.*
2. Open-country breeding places (swampy areas, roadside, drainage (fig. 2), and irrigation (fig. 3) ditches, and the edges of ponds (figs. 4 and 5), lakes, streams, and rivers)—*Psorophora pygmaea, P. jamaicensis, Aedes scapularis, A. taeniorhynchus, Culex pilosus, C. inhibitator, C. carcinophilus, C. atratus, C. nigripalpus, C. secutor, Uranotaenia sapphirina, U. lowii, Anopheles albimanus, A. grabhamii, Corethrella appendiculata.*
3. Crab holes—*Deinocerites cancer, Corethrella appendiculata.*
4. Tree holes—*Megarhinus portoricensis, Aedes mediovittatus, Corethrella appendiculata.*
5. Leaf bases of bromeliads and other plants (fig. 6)—*Wyeomyia mitchellii, Culex americanus, Megarhinus portoricensis, Corethrella appendiculata.*
6. Brackish water pools—*Psorophora pygmaea, Aedes sollicitans, A. taeniorhynchus, Culex inhibitator, C. bahamensis, C. nigripalpus, C. habilitator, C. atratus, Uranotaenia sp.,*[3] *Anopheles albimanus, A. grabhamii, A. crucians.*
7. Attached to roots and submerged stems of aquatic plants—*Mansonia indubitans, M. titillans.*

The following paragraphs give the species of mosquitoes collected by the writer in Puerto Rico with notes on their habits, abundance, and distribution.

1. *Wyeomyia* (*Wyeomyia*) *mitchellii* (Theobald).

This species is found breeding in the water contained in the leaf bases of epiphytic bromeliads in the higher altitudes of Puerto Rico.

[2] The distribution records indicated by (WAH) were made available by Dr. W. A. Hoffman of the School of Tropical Medicine. Records followed by HT indicate horse-trap collections and those followed by LT indicate light-trap collections. Unless otherwise indicated in the text, the remaining records refer to larval collections.

[3] A third species of this genus was taken in net collections in a thickly wooded area at Mayagüez in May, 1936. It represents a new species the description of which Dr. W. A. Hoffman has in manuscript.

The larvae are yellow in color and move about with a gliding motion over the debris in the leaf bases. The water in which they live is either slightly or distinctly acid, having a hydrogen ion concentration corresponding to a pH ranging between 4.0 and 6.5. The temperature of the water varies between 68° and 81° F., being lower on the higher points such as Bretton Peak in the Luquillo National Forest and higher at such points as Maricao. The adults are small bluish-green forms which have conspicuous white markings on the hind legs. Apparently they are not attracted to horses, since none were taken in a horse trap operated on Maricao Mountain during November 1935 at a time when larvae and pupae were present in the vicinity. At times they attack man but cannot be considered fierce biters.

Other species of mosquitoes associated with this form in bromeliads are *Culex americanus, Corethrella appendiculata,* and *Megarhinus portoricensis.*

Distribution Records: Maricao, August 15, 1935, No. 1;[4] Maricao Insular Forest, October 28, 1935, No. 1, January 20, 1935, No. 10, May 5, 1936; Luquillo National Forest, March 24, 1936, April 12, 1936, May 21, 1936.

2. *Psorophora (Grabhamia) pygmaea* Theobald.

The larvae of this species are large, have inflated air tubes, and prefer to live in temporary fresh-water ground pools containing little or no vegetation. However, they are able to develop in brackish water, for at Lake Guánica they were found in hoof-track pools containing 665 parts of chlorine per 100,000 parts of water.

The adults are large, well marked forms which are fierce biters during both night and day. In one case at Ponce on October 3, 1935, they were taken off white children playing in the bright sun shortly after noontime. No other observations of a similar nature were made during the investigation. They occasionally enter houses in search of blood; and they are also attracted to animals such as horses, since they usually were present in all horse-trap collections. A few were taken in light-trap collections.

The records available indicate that this species is fairly common on the southern coast of Puerto Rico.

Distribution Records: Central Aguirre, August 15, 1935; Santa Isabel, August 15, 1935; Ponce, October 3, 1935, No. 3; Guánica, October 9, 1935, No. 8; Mayagüez, November 14, 1935.

[4] Numbers following a locality and date record refer to the author's record file maintained during the course of the work.

3. *Psorophora* (*Grabhamia*) *jamaicensis* (Theobald).

The larvae of this form are slightly larger than those of *P. pygmaea.* They are found in temporary surface pools and occasionally in roadside ditches. Usually, they are the only species present in a given pool although *Anopheles albimanus, Culex inhibitator, C. pilosus,* and *Uranotaenia lowii* have been taken with it.

The adults are large and vicious biters. They were taken in large numbers in certain of the horse traps, especially those along the seacoast at Mayagüez. Occasionally adults were taken in small numbers in light-trap collections.

Distribution Records: Mayagüez, August 22, 1935, August 30, 1935, September 17, 1935, No. 1, November 14, 1935, November 29, 1935, No. 1, November 30, 1935, LT.

4. *Aedes* (*Ochlerotatus*) *nubilus* (Theobald).

The larvae of this form were not found in the water taken from crab holes. Dr. Stone, however, was able to recognize the adult from collections of mosquitoes taken in the entrances to the holes. Other species in company with this form were *Culex janitor, Deinocerites cancer,* and *Aedes taeniorhynchus.*

Distribution Record: Dorado, September 1, 1935.

5. *Aedes* (*Ochlerotatus*) *tortilis* (Theobald).

This form was first recognized in horse-trap collections from Las Mesas (elevation 1,000 feet) in Mayagüez. During the period October 3–9, 1935, 198 mosquitoes were taken in 7 collections and 95 percent of these were *Aedes tortilis.* Later (November 1935) the same species was taken in a horse trap on Maricao Mountain (elevation 3,000 feet), and during 1936 they were found in horse-trap collections in the regions along the sea coast. This species apparently prefers higher altitudes and it is suspected that this is the form that frequently annoys men working in the mountain forests of Puerto Rico.

Although an intensive search was made for the larvae not one was located.

Distribution Records: Mayagüez, August 7, 1935, HT, October 4, 1935, HT, November 14, 1935, HT, May 2, 1936, HT; Maricao Insular Forest, November 2, 1935, HT; November 3, 1935, HT.

6. *Aedes* (*Taeniorhynchus*) *sollicitans* (Walker).

This species was taken in both the larval and adult stages at several places along the southern coastal of Puerto Rico. In no case, however, were larvae taken in coastal salt marshes, which is the usual habitat for this species. The larvae were first taken in

hoof-track pools along the edge of Lake Guánica. Although the water in the lake is only slightly brackish (25 parts Cl. to 100,000 parts of water), the water in the small pools adjacent to it becomes concentrated by evaporation. Some of these pools have a chlorine content as high as 900 parts per 100,000 parts of water. Large numbers of larvae of this species were found in this region at various times. The presence of this species in pools having a chlorine content not greater than 900 parts is considered unusual. In the tidal marshes of the eastern coast of the United Sates this species prefers to live in pools having a high chlorine content, it oftentimes being equal to, or greater than, that of coastal sea water. Other species were found breeding in pools with *sollicitans*, among them *Anopheles albimanus, Culex bahamensis,* and *C. nigripalpus.* The adults are active and attack freely at night and during the day.

Distribution Records: Guánica, October 25, 1935, January 23, 1936, No. 2, May 18, 1936; Aguirre, October 30, 1935, No. 2, October 31, 1935, No. 1; Guayama, October 31, 1935, No. 5; San Juan, October 4, 1930 (WAH).

7. *Aedes* (*Taeniorhynchus*) *taeniorhynchus* (Wiedemann).

The larvae of this species are found in pools of a semipermanent or permanent nature in the coastal plain region. Apparently they do not have any particular preference for any special kind of water since they were taken in clean, dirty, fresh, and brackish pools. Other species found with them in fresh water pools were *Anopheles albimanus* and *Culex nigripalpus.* In the brackish pools at Lake Guánica *C. bahamensis* and *A. albimanus* were associated with this species. The adults are quite numerous in certain regions and were taken in large numbers in two of the horse traps operated near the seashore at Mayagüez.

Distribution Records: Dorado, November 7, 1935 (WAH), September 1, 1935; Guánica, October 9, 1935, No. 1, October 25, 1935, No. 1; Mayagüez, August 24, 1935, HT, September 11, 1935, No. 1, November 14, 1935, HT; San Juan, October 1932 (WAH).

8. *Aedes* (*Finlaya*) *mediovittatus* (*Coquillett*).

The usual larval habitat of this species is tree holes. In Puerto Rico many suitable cavities containing water are found in the native mango trees. This species is not entirely restricted to tree holes, since in one case larvae were found associated with the larvae of *Aedes aegypti* breeding in stone crocks which were piled edgewise in a greenhouse at Mayagüez. The presence of these two species in this situation represents an overlapping of habitats. The larvae found

in tree holes are often associated with two species of predatory mosquito larvae, *Megarhinus portoricensis* and *Corethrella appendiculata*. The pH of water in these situations is usually very nearly neutral. The adults are conspicuously marked with white. They were taken in light traps in a few cases.

Distribution Records: Pueblo Viejo, August 31, 1935, No. 1; Mayagüez, September 18, 1935, No. 1, October 4, 1935, No. 2. November 7, 1935, No. 3, December 6, 1935, No. 1; Guayama, October 26, 1930 (WAH); Yauco, April 1932 (WAH).

9. *Aedes* (*Howardina*) *aegypti* (Linnaeus).

Aedes aegypti is one of the two species of mosquitoes that is nearly always found in the neighborhood of dwellings in Puerto Rico. In the poorer, thickly settled regions the rain water is saved either for drinking or washing or both. The receptacles used to collect the water, either barrels or cisterns, usually are not covered and they are therefore easily accessible to the females for depositing their eggs.

This species was taken in all parts of the coastal plains of Puerto Rico and in many of the towns high in the mountains.

The adults are fierce biters and attack freely and without warning during the day and early in the evening.

Distribution Records: Mayagüez, July 31, 1936, No. 4, August 1, 1935, No. 1, August 3, 1935, No. 1, August 22, 1935, No. 2, October 21, 1935, No. 1, October 21, 1935, No. 1, December 4, 1935, No. 1, February 15, 1936, No. 5, April 10, 1936, No. 2, April 9, 1936, No. 1; Rincón, August No. 4; Guánica, October 9, 1935, No. 2; Fajardo, November 13, 1935, No. 5 A; San Juan, December 19, 1935, No. 2, October 1, 1926 (WAH); Catano, December 19, 1935, No. 4; Hormigueros, April 3, 1936, No. 1; San Germán, April 3, 1936, No. 3; Guayanilla, April 6, 1936, No. 1; Cabo Rojo, April 7, 1936, No. 1; Lajas, April 7, 1936, No. 8; Aguada, April 8, 1936, No. 3; Aguadilla, April 8, 1936, No. 7; San Sebastián, April 8, 1936, No. 10; Quebradillas, April 9, 1936, No. 4; Camuy, April 9, 1936, No. 6; Hatillo, April 9, 1936, No. 7; Arecibo, April 9, 1936, No. 8; Peñuelas, April 15, 1936, No. 1; Ponce, April 15, 1936, No. 2.

10. *Aedes* (*Ochlerotatus*) *condolescens* Dyar & Knab.

A form suspected to be this species was taken by sweeping an area covered with dead leaves in a deeply shaded wood in Mayagüez. An examination of the male genitalia substantiated this identification. The larva is unknown.

Distribution Record: Mayagüez, May 21, 1936.

11. *Aedes* (*Ochlerotatus*) *scapularis* (*Rondani*).

This species is represented by a single larva taken on the edge of a roadside ditch at Mayagüez. It was associated with *Dixa* sp., *Corethrella appendiculata,* and *Uranotaenia lowii.*

Distribution Record. Mayagüez, May 16, 1936, No. 1.

12. *Mansonia* (*Mansonia*) *titillans* (Walker).

Males and females of this form were taken in small numbers from the light trap at the Experiment Station in Mayagüez during the fall of 1935. No specimens were taken in horse traps, and it is not known if the females attack man or animals. The larvae were not taken.

Distribution Records: Mayagüez, September 26, 1935, LT. November 25, 1935, LT.

13. *Mansonia* (*Mansonia*) *indubitans* Dyar & Shannon.

This species previously was known only from adults. During these investigations the larvae were taken for the first time attached to the submerged stems of *Pistia stratiodes.* Larvae brought into the laboratory reattached themselves to stems of *Pistia* and developed to maturity. A description of the larva follows:

Description of the larva of M. indubitans: Length 6–7 mm. Head one-fourth wider than long; antenna (fig. 7) long and slender, longer than width of head, a large hair tuft at the middle of the basal portion, terminal portion long and slender with an articulation at the distal end, two long terminal setae present arising from end of basal portion equal in length to terminal portion of antenna. Head hairs small and in multiple tufts. Lateral comb at eighth segment of eight to ten scales arranged in a single row, each scale fringed outwardly with large spines. Air tubes (fig. 8) less than twice as long as wide, the basal portion broad, a terminal portion sharply attenuated with saw-like teeth on upper edge; a pair of hair tufts on lower portion of basal portion, a single pair of hairs on upper edge of tube at junction of basal and terminal portions; pecten absent. Anal segment nearly twice as long as wide, ringed by dorsal plate and covered with fine pilose setae; dorsal tuft of many long hairs, all joined at base; lateral hair, a small tuft of long hairs; ventral brush of long hairs. Anal gills four, pointed and shorter than anal segment. (Larval and pupal skins and reared male in the collection of the United States National Museum.)

The females were taken in numbers from light and horse traps. It is not known if they enter houses in search of blood. The records given below are the first for the West Indies.

Distribution Records: Lake Cartagena, November 16, 1935, HT, November 23, 1935, No. 5, HT; Sabana Grande, May 22, 1936, LT.

14. *Deinocerites cancer* (Theobald).

The larvae of this form develop in the water found in crab holes near the sea coast. The adults may be found resting in the mouths of crab holes during the day. Males have been taken from light traps at night, and females engorged with blood have been found in horse traps. The females have been observed also in houses at night.

Distribution Records: Dorado, September 1, 1935; Mayagüez, November 14, 1935, HT.; Central Aguirre, July 15, 1935.

15. *Culex* (*Mochlostyrax*) *pilosus* Dyar & Knab.

The larvae of this form were taken in a roadside ditch in association with many other larvae. The larvae rest on their backs on the bottom of the pool and when disturbed exhibit a peculiar wiggling motion of the hinder parts of the body which is different from that of any other tropical *Culex* encountered. The larvae were fairly numerous during the latter part of November 1935 but were not encountered again until May 1936. Larvae of *Uranotaenia* are nearly always found associated with this species and quite frequently *Anopheles albimanus* and *Psorophora jamaicensis* were present as well.

Distribution Records: Mayagüez, November 26, 1935, No. 1, November 27, 1935, No. 3, November 29, 1935, No. 1, May 31, 1936.

16. *Culex* (*Mochlostyrax*) *inhibitator* Dyar & Knab.

This species is one of the most abundant of the *Culex* group. It develops in roadside ditches, swampy areas, edges of ponds (fig. 4), and in both fresh and brackish water. In general, it is found in all types of clean water, rarely being found in water that is polluted with sewage (fig. 5). In one instance it was taken in water containing 770 parts of chlorine per 100,000 parts of water (Añasco River).

The adults of this species were taken in a horse trap at Lake Cartagena. No other evidence relative to their blood-sucking habits is available.

Distribution Records: Mayagüez, August 21, 1935, No. 3, November 29, 1935, No. 1, December 10, 1935, No. 3, January 8, 1936, No. 1, January 10, 1936, No. 1, January 15, 1936, No. 1, March 15, 1936, No. 1; Hormigueros, September 17, 1935, No. 3; Guánica, October 9, 1935, No. 4; Rincón, October 10, 1935, No. 5; San Anto-

nio, October 10, 1935, No. 1; Lake Cartagena, November 11, 1935, No. 4; Guanajibo, Mayagüez, November 7, 1935, No. 2; San Sebastián, January 17, 1936, No. 1; Dorado, February 1932, (WAH).

17. *Culex* (*Mochlostyrax*) *carcinophilus* Dyar & Knab.

Only the larval stage of this species was taken. It is reputed to develop in crab holes but these specimens were taken along the edge of Lake Cartagena in water containing a large amount of floating vegetation.

Distribution Records: Lake Cartagena, November 11, 1935, November 23, 1935.

18. *Culex* (*Melanoconion*) *atratus* Theobald.

The larvae of this species were taken in pools of a more or less permanent nature containing some vegetation. They were associated with *Anopheles albimanus* and *Uranotaenia* sp.

The adults were not recognized in house, light, or horse-trap collections.

Distribution Records: Mayagüez, August 22, 1935, No. 1, October 7, 1935, No. 1, October 8, 1935, No. 2, November 7, 1935, No. 4; Dorado, February 1932 (WAH), September 1, 1935, No. 4; San Juan, April 26, 1929 (WAH).

19. *Culex* (*Melanoconion*) *americanus* (Neveu-Lemaire).

The larvae of this species were taken in the leaf bases of the following three plants: (*a*) The bromeliad *Guzmania berteroniana:* (*b*) "malanga", *Caladium colocasia* (fig. 6); and (*c*) a plant without any common name, *Dieffenbachia sequine.* The bromeliads found in the mountainous regions of Puerto Rico are the most important and most abundant of the host plants mentioned above.

The water in the leaf bases of the bromeliads in which these larvae live always is acid. In some cases larvae were taken from bromeliad water having a pH of 3.8. Usually, however, the pH range is between 4 and 6. Other mosquito larvae present in bromeliad leaf bases are *Megarhinus protoricensis, Wyeomyia mitchellii,* and *Corethrella appendiculata.*

The adults were not taken in horse-trap collections in regions where the larvae of this species were abundant, and it is assumed, from this, that they do not usually attack warm-blooded animals.

Distribution Records: Maricao, August 15, 1935, No. 1, August 25, 1935, No. 1, October 13, 1935, No. 1, October 28, 1935, No. 1, November 7, 1935, No 1, January 28, 1936, No. 10, May 5, 1936, No. 1, May 21, 1936; Luquillo National Forest, March 24, 1936, No. 1, May 21, 1936, No. 1.

20. *Culex* (*Culex*) *bahamensis* Dyar & Knab.

The larvae of this species are restricted to brackish water. On one occasion the water in a large pool at Salinas appeared black because of the large number of larvae present. The larvae also were taken in the hoof-track pools along the edge of Lake Guánica in water having a chlorine range of from 195 to 900 parts per 100,000 of water. Species associated with *bahamensis* in brackish water pools were *Aedes sollicitans. Anopheles albimanus* and *Culex nigripalpus.*

Distribution Records: Salinas, October 31, 1935, No. 8; Guánica, January 23, 1936, No. 1; Dorado, August 15, 1930 (WAH.)

21. *Culex* (*Culex*) *habilitator* Dyar & Knab.

The larvae of this species are able to develop in either fresh or brackish water. They were taken in large numbers from brackish pools (185 parts Cl per 100,000) along the Añasco River and in the brackish hoof-track pools at Lake Guánica. They were also taken in the swampy fresh-water areas in Mayagüez. Other larvae associated with this species were *Anopheles albimanus* and *Uranotaenia lowii.*

During the day, the adults may be found resting under dried leaves in shaded places in the forest. Their feeding habits were not determined.

Distribution Records: Mayagüez. July 27, 1935, No. 1, August 21, 1935, No. 1, May 7, 1936, No. 1; Ensenada, October 9, 1935, No. 1, October 17, 1935. No. 1; Guánica, October 9, 1935, No. 5; Dorado, October 1, 1930 (WAH).

22. *Culex* (*Culex*) *nigripalpus* Theobald.

This species is probably the most abundant of all tropical forms of *Culex.* It is found breeding in large numbers in the open country and in the towns, in fresh and brackish pools and in clean and sewage-polluted waters. The larvae have been found associated with *Uranotaenia lowii, Corethrella appendiculata, Aedes taeniorhynchus, Anopheles albimanus, A. grabhamii, Culex quinquefasciatus, Aedes sollicitans, Anopheles crucians,* and *Culex bahamensis.*

The adults rarely enter houses.

Distribution Records: Mayagüez, July 8, 1935, No. 1, July 25, 1935, No. 2, August 22, 1935, No. 3, August 28, 1935, No. 2, September 7, 1935, No. 1, September 9, 1935, No. 1, September 11, 1935, No. 2, September 13, 1935, No. 1, September 18, 1935, No. 2, September 29, 1935, No. 1, October 7, 1935, No. 2, December 10, 1935, No. 4, December 14, 1935, No. 2; Añasco, August 20, 1935, No. 5. August 19, 1935, No. 1, September 19, 1935, No. 3; Hormigueros,

September 17, 1935, No. 4; Guánica. October 9, 1935, No. 6, January 23, 1936, No. 2; Ensenada, October 17, 1935, No. 1, October 25, 1935, No. 4 Las Marías, January 17, 1936, No. 2; Dorado, October 1930 (WAH).

23. *Culex* (*Culex*) *janitor* Theobald.

This form is known only from adults collected in the mouths of crab holes. Dr. Hoffman has taken the larvae in crab holes at Pueblo Viejo.

Distribution Records: Dorado, September 1, 1935; Mayagüez, April 29, 1936, No. 3; Pueblo Viejo, November 2, 1935 (WAH).

24. *Culex* (*Culex*) *secutor* Theobald.

The larvae of this species appear to prefer water which is cool, since they are found in permanent pools at high altitudes or in deeply shaded pools in the lowlands. They were taken in the same pools with the larvae of *Chaoborus brasiliensis.*

Distribution Records: Mayagüez, October 17, 1935, No. 1, February 15, 1936, No. 6; Maricao, January 28, 1935, No. 9; Luquillo National Forest, April 12, 1936.

25. *Culex* (*Culex*) *quinquefasciatus* Say.

This species is probably the most abundant form found in the towns and cities of Puerto Rico. It is found around habitations in nearly all parts of Puerto Rico with the exception of certain high mountainous areas. It is able to develop in clear water or in water heavily laden with sewage. Street gutters (fig. 1), drainage ditches (fig 2), tin cans, etc., are suitable places where water may collect and breeding result. It usually does not have the association of other mosquito larvae although rarely it is found with *Anopheles albimanus, Aedes aegypti,* and *Culex nigripalpus.*

The adults enter houses in great numbers in search for blood, and from the standpoint of annoyance it is the most important species. It is probably the only mosquito vector of filariasis in Puerto Rico. This disease is of some importance on the Island.

Distribution Records: Mayagüez, July 10, 1935, No. 1, July 4. 1935, No. 1, July 11, 1935, No. 2, August 1, 1935, No. 2, August 18, 1935, No. 1, August 21, 1935, No. 4, August 27, 1935, No. 1, September 12, 1935, No. 1, September 29, 1935, No. 1, December 10, 1935, No. 5; December 11, 1935, No. 1, December 11, 1935, No. 2, December 11, 1935, No. 3, December 9, 1935, No. 1, December 13, 1935, No. 4, December 14, 1935, No. 3, January 4, 1936, No. 1, February 15, 1936, No. 5, February 19, 1936, No. 1; Isabela, August 19, 1935, No. 1; Rincón, August 26, 1935, No. 2; Fajardo, Novem-

ber 13, 1935, No. 5; San Juan, November 12, 1935, No. 5, December 19, 1935, No. 1, October 1, 1926 (WAH); Cataño, December 19, 1935, No. 5; Maricao, January 6, 1936, No. 1, April 14, 1936, No. 1; Adjuntas, January 6, 1936, No. 4; Jayuya, January 6, 1936, No. 4; Hormigueros, April 3, 1936, No. 2; Guayanilla, April 6, 1936, No. 2; Sabana Grande, April 6, 1936, No. 4; Añasco, April 7, 1936, No. 4; Ponce, April 13, 1936, No. 4.

26. *Megarhinus* (*Megarhinus*) *portoricensis* Roeder.

The larva of this species was the largest of any taken in Puerto Rico. Its habitat is restricted to tree holes in association with *Aedes mediovittatus* and in leaf bases of bromeliads in association with *Culex americanus* and *Wyeomyia mitchelbii*. It is a predator on other mosquito larvae and, if necessary, cannibalistic. Its restricted habitat does not allow its predacious habit to be of any significance in the general Puerto Rican mosquito problem.

A single male was taken by M. R. Smith in a coffee grove in Mayagüez during midday on September 18, 1935.

Distribution Records: Mayagüez, September 18, 1935, No. 1. December 10, 1935, No. 1.

27. *Uranotaenia sapphirina* (Osten-Sacken).

Although *Uranotaenia* larvae are very common in all parts of the coastal plain of Puerto Rico, the two common species cannot be readily separated on larval characters. On the basis of rearings and light-trap collections it appears that this species is present only in small numbers.

The adults do not attack man.

Distribution Records: Cabo Rojo, November 18, 1935, No. 1, Mayagüez, November 8, 1935.

28. *Uranotaenia lowii* Theobald.

This species appeared with regularity and in greater numbers than *U. sapphirina* both in light-trap collections and in reared material during the year. The larvae of this group prefer the water containing much vegetation. They are found in considerable numbers in almost all open-country situations. In one or two cases they were taken in brackish water pools.

As far as known the adults do not attack man or animals.

Distribution Records: Mayagüez, August 22, 1935, No. 1, September 18, 1935, No. 2, October 1, 1935, No. 1, October 8, 1935, No. 3, November 26, 1935, No. 1; Guánica, October 9, 1935, No. 5, October 9, 1935, No. 8; Rincón, October 10, 1935, No. 5; Lake Cartagena, November 11, 1935, No. 4.

29. *Anopheles* (*Nyssorhynchus*) *albimanus* Wiedemann.

This species is the most abundant of the Puerto Rican anophelines. It is found in all parts of Puerto Rico, yet the most suitable conditions for its development are found in the coastal plain.

The larvae are commonly found in roadside, irrigation (fig. 3), or drainage ditches, in overnight reservoirs (fig. 5), in swamps, and along the margins of streams, rivers, ponds, (fig. 4) and lakes. They also have been found in street gutters, tin cans, and water barrels, but the indications are that they prefer situations in open country. They appear to breed with equal ease in brackish and in fresh water, as they were taken in water having 950 parts of chlorine per 100,000 parts of water.

The adults are active only at night and as many as 1,000 were taken in one horse trap in one night. During the day they remain in hiding and consequently little is known of their diurnal activities. In a few cases the females were recovered by sweeping and in one case a female was taken from the mouth of a crab hole.

Its importance as a carrier of the causative organism of malaria cannot be over-estimated.

Distribution Records: Mayagüez, July 8, 1935, No. 2, July 10, 1935, No. 3, July 31, 1935, No. 1, August 14, 1935, No. 1, August 21, 1935, No. 2, August 22, 1935, No. 1, September 11, 1935, No. 1, September 17, 1935, No. 1, September 29, 1935, No. 1, October 4, 1935, No. 1, October 7, 1935, No. 1. October 8, 1935, No. 1, November 7, 1935, No. 4, November 26, 1935, No. 1, November 27, 1935, No. 3, November 29, 1935, No. 1, December 10, 1935 No. 3, December 13, 1935, No. 1, January 8, 1936, No. 2, January 10, 1936, No. 1, February 15, 1936, No. 5, March 15, 1936, No. 1, March 16, 1936, No. 3; Rincón, August 20, 1935, No. 4; Hormigueros, August 16, 1935, No. 1, September 17, 1935, No. 2; Isabela, August 19, 1935, No. 3; Añasco, August 20, 1935, No. 4, September 19, 1935, No. 1; Pueblo Viejo, August 31, 1935, No. 3, December 18, 1935, No. 1; Río Piedras, August 31, 1935, No. 4; Dorado, September 1, 1935, No. 1; Toa Alta, September 1, 1935, No. 5; Vega Baja, September 2, 1935, No. 1; November 12, 1935, No. 3; Manatí, September 2, 1935, No. 2; Barceloneta, September 2, 1935 No. 3; Ponce, October 3, 1935, No. 2; Guánica, October 9, 1935, No. 5, October 25, 1935, No. 1; January 23, 1936, No. 1; Ensenada, October 17, 1935, No. 1; Aguada, October 10, 1935, No. 3; Guánica, October 25, 1935, No. 1; Aguirre, October 30, 1936, No. 3; October 31, 1935, No. 1; Guayama, October 31, 1935, No. 4; Arroyo, October 31, 1935, No. 5; Salinas, October 31, 1935, No. 6; Quebradillas, November 8, 1935,

No. 1; Hatillo, November 11, 1935, No. 1; Boquerón, November 11, 1935, No. 1; Lake Cartagena, November 11, 1935, No. 4; Arecibo, November 12, 1936, No. 1; Manatí, November 12, 1935, No. 2; Bayamón, November 12, 1935, No. 4; December 18, 1935, No. 2; San Juan, November 12, 1935, No. 6; Carolina, November 13, 1935, No. 1; Río Grande, November 13, 1935, No. 2; Mameyes, November 13, 1935, No. 3; Luquillo, November 13, 1935, No. 4; Fajardo, November 13, 1935, No. 6; Ceiba, November 13, 1935, No. 7; Naguabo, November 13, 1935, No. 8; Humacao, November 13, 1935, No. 9; Yabucoa, November 13, 1935, No. 10; Maunabo, November 7, 1935, No. 4; Cataño, December 19, 1935, No. 3; Adjuntas, January 6, 1936, No. 3; Las Marías, January 17, 1935, No. 2.

30. ***Anopheles*** (***Anopheles***) ***crucians*** (Wiedemann).

This species is represented by a single larva taken in brackish water in a hoof print at Lake Guánica. This constitutes the first record of the species in Puerto Rico.

Distribution Record: Guánica, January 23, 1935, No. 2.

31. *Anopheles* (*Anopheles*) *grabhamii* Theobald.

In so far as abundance in Puerto Rico is concerned this species ranks second among the anophelines. The larvae are found in fresh and in slightly brackish water in habitats similar to those in which larvae of *A. albimanus* are found.

The adults were taken in horse traps and occasionally in light trap and net collections.

Distribution Decords: Dorado, September, 1935, No. 3; Mayagüez, December 10, 1935, No. 4.

32. *Anopheles* (*Anopheles*) *vestitipennis* Dyar & Knab.

The larvae of this species were not taken, but adults were present in various horse-trap collections. In abundance it ranks third among the anophelines.

Distribution Records: Mayagüez, September 17, 1935, HT, October 15, 1935, HT; Cabo Rojo, December 16, 1935, HT, January 4, 1936, HT.

33. *Corethrella appendiculata* Grabham.

The larva of this species, although small in size, is an effective predator on first-and second-stage *Culex* larvae. It is found in many open-country habitats having clean water, in crab holes, and in large numbers in the leaf bases of bromeliads.

It probably is of little value in reducing the numbers of mosquitoes attacking man.

Distribution Records: Mayagüez, August 1, 1935, No. 3, August 21, 1935, No. 3, September 9, 1935, No. 1, September 18, 1935, No. 1, November 27, 1935, No. 1; Maricao, August 25, 1935, No. 1, October 13, 1935, No. 1, January 28, 1936, No. 10; Dorado, September 1, 1935, No. 2.

34. *Chaoborus brasiliensis* Theobald.

Adults of this species were taken in large numbers from light-trap collections, yet the larvae were encountered in only one instance. The larvae were taken in a pool formed by a spring in heavily shaded woods. Other larvae in the pool were *Culex secutor* and *C. inhibitator*. Although the larva is predacious it probably does not materially aid in reducing the number of mosquitoes attacking man.

The records below are the first for the West Indies.

Distribution Records: Mayagüez, September 10, 1935, LT, February 15, 1936.

A Key to the Species of Mosquitoes[5] Occurring in Puerto Rico

Table of Genera

ADULTS

1. Base of hind coxa in line with upper margin of lateral metasternal sclerite 2
   Base of hind coxa distinctly below upper margin of lateral metasternal sclerite 3
2. Tuft of setae present on metanotum ..... *Wyeomyia*
   Setae absent on metanotum ..... *Megarhinus*
3. Scutellum crescent shaped ..... *Anopheles*
   Scutellum trilobed 4
4. Anal vein extending beyond fork of cubitus 5
   Anal vein ending opposite or at base of cubital fork ..... *Uranotaenia*
5. Postspiracular setae present 6
   Postspiracular setae absent 8
6. Spiracular setae present ..... *Psorophora*
   Spiracular setae absent 7
7. Wing scales narrow ..... *Aedes*
   Wing scales broad ..... *Mansonia*
8. Antennae longer than proboscis ..... *Deinocerites*
   Antennae not longer than proboscis ..... *Culex*

LARVAE

1. Eighth segment of abdomen provided with a distinct elongate dorsal siphon or respiratory tube 2
   Eighth segment without a distinct elongate dorsal siphon ..... *Anopheles*
2. Anal segment without ventral brush ..... *Wyeomyia*
   Anal segment with ventral brush 3

[5] Only the Culicinae or biting mosquitoes are considered.

3. Eighth segment laterally without pecten, having a plate with two coarse setae ..... *Megarhinus*
   Eighth segment laterally with pecten consisting of small teeth 4
4. Air tube without pecten ..... *Mansonia*
   Air tube with pecten 5
5. Air tube with several pairs of ventral tufts ..... *Culex*
   Air tuve with a single pair of tufts 6
6. Head elongate, elliptical ..... *Uranotaenia*
   Head nearly circular or transverse 7
7. Mandible projecting laterally ..... *Deinocerites*
   Mandible concealed 8
8. Anal segment ringed by dorsal plate with hair tufts piercing ring .. *Psorophora*
   Anal segment not ringed by plate, or if ringed the hair tufts posterior to the ring ..... *Aedes*

Table of Species of Psorophora

ADULTS

1. Femora and tibiae distinctly white speckled, first tarsal segment with a mesial white band ..... *jamaicensis*
   Femora and tibiae scarcely white speckled, first tarsal segment without mesial white band ..... *pygmaea*

LARVAE

1. Head hairs single ..... *pygmaea*
   Head hairs multiple ..... *jamaicensis*

Table of Species of Aedes

ADULTS

1. Tarsi not white marked 2
   Tarsi white marked 5
2. Mesonotum marked with gold ..... *tortilis*
   Mesonotum marked with silver 3
3. Silver on mesonotum in a broad stripe not reaching scutellum 4
   Silver on mesonotum in a broad or narrow line reaching scutellum ... *nubilus*
4. Abdomen with a median whitish-brown longitudinal band ..... *scapularis*
   Abdomen without such a band ..... *condolescens*
5. Proboscis of female ringed with white 6
   Proboscis of female not ringed with white 7
6. Abdomen with a longitudinal dorsal stripe ..... *sollicitans*
   Abdomen without a longitudinal dorsal stripe ..... *taeniorhynchus*
7. Mesonotum dark with lyre-shaped silvery markings ..... *aegypti*
   Mesonotum light with three central narrow silvery lines ..... *mediovittatus*

LARVAE

1. Anal segment ringed by plate 3
   Anal segment not ringed by plate 2
2. Brush of anal segment with a more or less well developed triangular chitinous plate ..... *mediovittatus*
   Without this structure ..... *aegypti*

3. Air tube with tuft within pecten 4
   Air tube with tuft beyond pecten 5
4. Lateral comb of eighth segment of a few scales ..... *nubilus*
   Lateral comb of eighth segment of many scales in a triangular plate ..... *tortilis*
5. Comb scales pointed at tip, thorn shaped ..... *sollicitans*
   Comb scales with feathered tips 6
6. Anal segment short, gills budlike ..... *taeniorhynchus*
   Anal segment normal, gills moderate ..... *scapularis*
   The larva of *A. condolescens* is unknown.

Table of Species of Mansonia

ADULTS

1. Large reddish forms with palpi over one-third as long as proboscis ..... *titillans*
   Small black and white forms with palpi not as long as one third of proboscis ..... *indubitans*

LARVAE

1. Antenna stout with a terminal digit drawn out but distinctly smaller than the antenna itself ..... *titillans*
   Antenna slender with a terminal digit of the same size as antenna and continuous with it ..... *indubitans*

Table of Species of Uranotaenia

ADULTS

1. Tarsi all darky colored ..... *sapphirina*
   Tarsi marked with white ..... *lowii*

LARVAE*

1. Anal gills pointed ..... *sapphirina*
   Anal gills blunt ..... *lowii*

Table of Species of Culex

ADULTS

1. Vertex of head with narrow curved scales 2
   Vertex of head often with small flat scales or many erect forked scales, generally with the tarsi unmarked 8
2. Tarsal joints white marked 3
   Tarsal joint black 7
3. Proboscis of female with a distinct central white ring ..... *bahamensis*
   Proboscis of female without a distinct white ring 4
4. Proboscis of female with a broad pale area beneath, which may be continued on the upper side as a very narrow ring at about the outer third ..... *habilitator*
   Proboscis entirely black 5
5. Abdomen with basal segmental white bands widening on the sides ..... some specimens of *nigripalpus*
   Abdomen without basal segmental bands 6

* Final determination of the species in this genus must depend upon an examination of the adult.

6. Femora whitish below basally, occiput without erect black bristles---- *secutor*
Femora entirely whistish below, occuput with erect black bristles---- *janitor*
7. Mesonotum with narrow curved scales---- *quinquefasciatus*
Menosotum with fine hair-like scales---- *nigripalpus*
8. Palpi over one-third the length of proboscis---- *americanus*
Palpi less than one-third the length of proboscis---- *pilosus, inhibitator, carcinophilus, atratus*

LARVAE

1. Lateral comb of eighth segment consisting of spines in a single row---- *pilosus*
Lateral comb with many scales in a triangular patch---- 2
2. Antennae uniformly shaped, apical portion not more slender---- 3
Antennae with the apical portion more slender than the basal portion--- 4
3. Abdominal hairs in coarse tufts---- *americanus*
Abdominal hairs normal, two basal tufts of tube within pecten---- *janitor*
4. Anal gills only two---- *bahamensis*
Anal gill four---- 5
5. Air tube with four or more paired tufts, the subapical one moved out of line at outer third of tube---- 6
All of the tufts on air tube in line---- 8
6. Air tube over five times as long as wide, without marked tapering---- 7
Air tube less than five times as long as wide, tapering terminally, subfusiform---- *quinquefasciatus*
7. Air tube about eight times as long as wide, with short three-haired tufts---- *habilitator*
Air tube about seven times as long as wide or less, hairs of tube often single---- *nigripalpus*
8. Air tube with long well defined tufts---- 9
Air tube with small double hair tufts---- *carcinophilus*
9. Body spicular pilose---- 10
Body glabrous---- *secutor*
10. Hair tufts on tube all of about the same length---- *atratus*
Hair tufts on tube with the basal one long, the rest progressively shorter---- *inhibitator*

Culex antillum-magnorum Dyar is not considered to be a valid species but a form of *C. americanus* and, therefore, is not included in this key.

Table to Species of Anopheles

ADULTS

1. Tarsi marked with white---- 2
Tarsi dark---- *crucians*
2. White markings on hind tarsi different from those of fore and mid tarsi---- *albimanus*
White markings on hind tarsi similar to those of fore and and mid tarsi 3
3. Wing scales distinctly inflated---- *grabhamii*
Wing scales narrow and linear---- *vestitipennis*

LARVAE

1. Teeth of comb alternatingly long and short---------- *vestitipennis*
   Teeth of comb both long and short, irregular---------- 2
2. Dorsal float hairs present on abdominal segments 1–7---------- *albimanus*
   Dorsal float hairs present on abdominal segments 2–7---------- 3
3. Anterior pair of float hairs smaller than others---------- *crucians*
   Float hairs all equal in size---------- *grabhamii*

The following genera are represented by a single species in Puerto Rico: *Wyeomyia, Magarhinus,* and *Deinocerites.*

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FIG. 1.—Street culvert at Fajardo found to contain larvae of *Culex quinquefasciatus*.

FIG. 1.—Street culvert at Fajardo found to contain larvae of *Culex quinquefasciatus*.

FIG. 2.—A drainage canal in one of the densely populated sections of Mayagüez which contained large numbers of *Culex quinquefasciatus*.

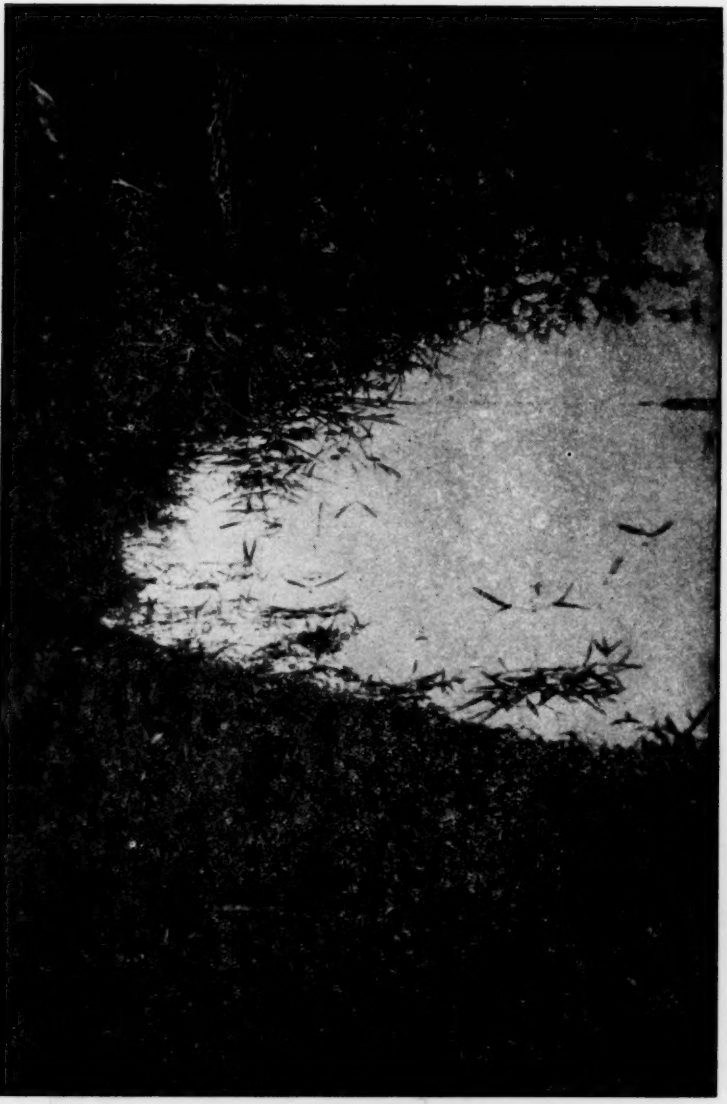


FIG. 3.—A secondary irrigation ditch containing large numbers of the larvae of *Anopheles albimanus*. Mayagüez, P. R.

FIG. 3.—A secondary irrigation ditch containing large numbers of the larvae of *Anopheles albimanus*. Mayagüez, P. R.

FIG. 4.—A small pond well stocked with fish at Mayagüez found to contain larvae of *Anopheles albimanus* and *Culex inhibitator* along its grassy margins.

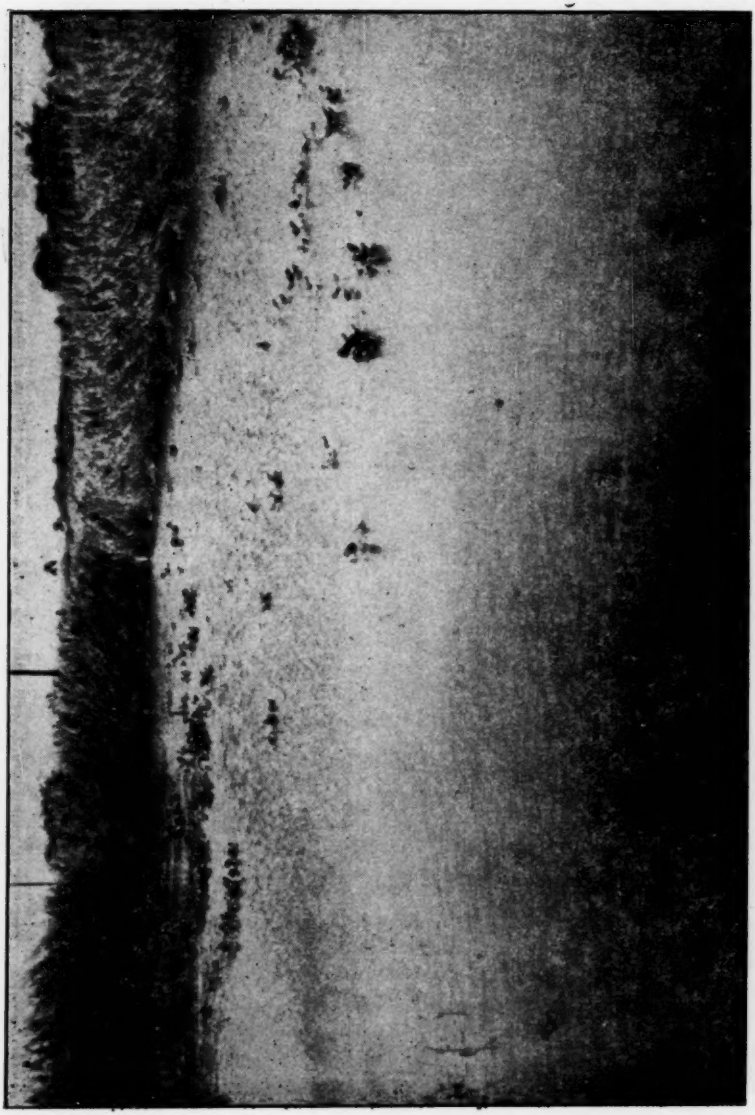


FIG. 5.—An overnight reservoir near Lake Cartagena containing larvae of *Anopheles albimanus*, *Culex inhibitator* and *Uranotaenia* spp.

FIG. 5.—An overnight reservoir near Lake Cartagena containing larvae of *Anopheles albimanus*, *Culex habitator* and *Uranotaenia* spp.

FIG. 6.—Larvae of *Culex americanus* were found in the leaf bases of *Caladium colocasia*, commonly known as "malanga."

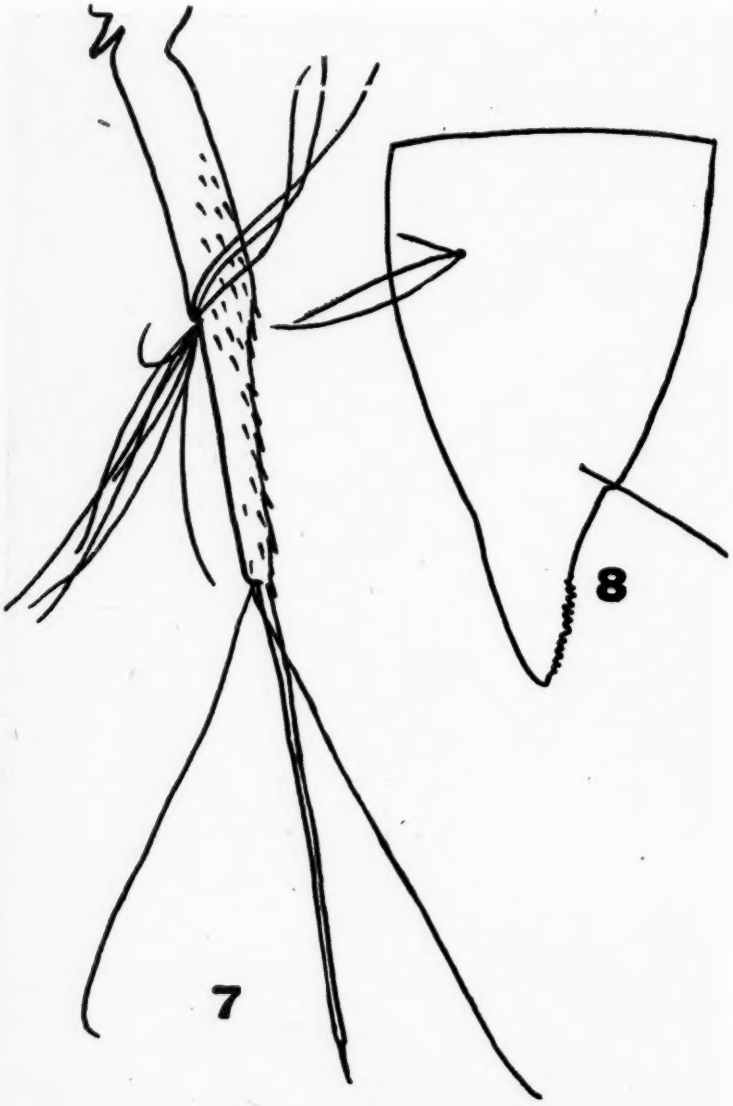
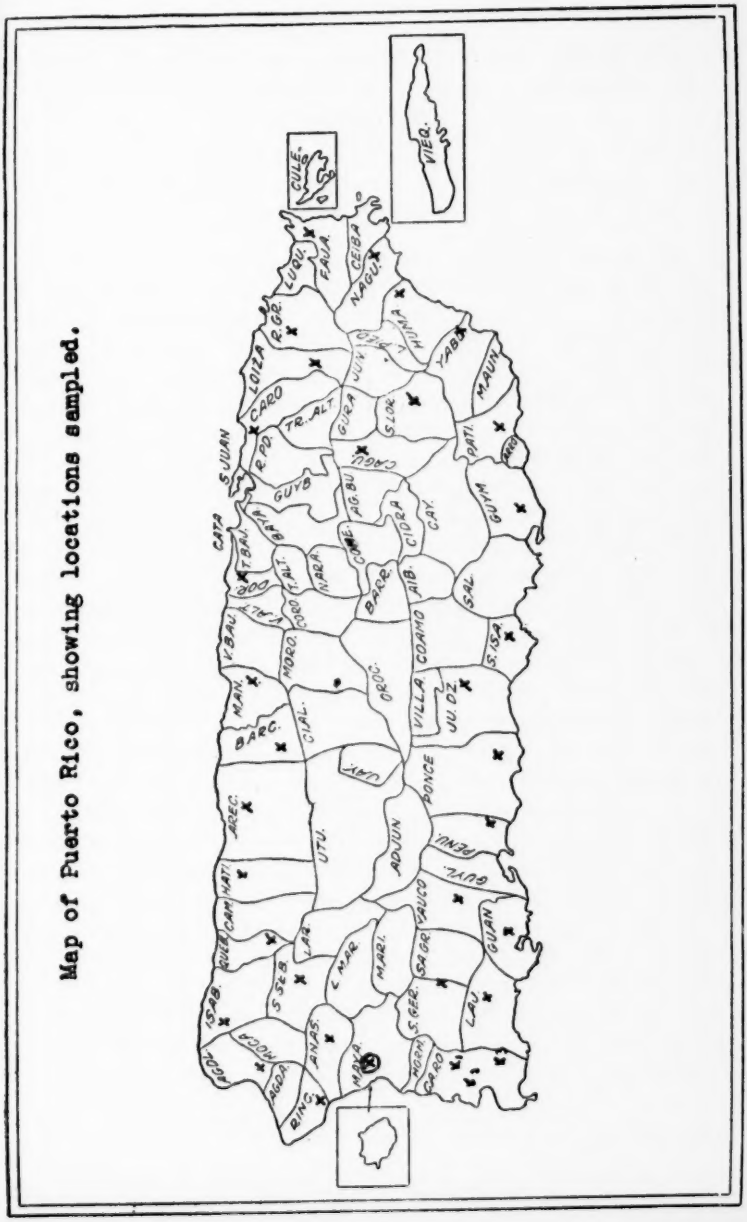


FIG. 7.—*Mansonia (Mansonia) indubitans:* **Antenna of larva.**
FIG. 8.—*Mansonia (Mansonia) indubitans:* **Air tube of larva.**



Map of Puerto Rico, showing localities sampled.

DAMAGE TO SEA ISLAND COTTON BY THE WEST INDIAN BLISTER MITE (*ERIOPHYES GOSSYPII* BANKS[1]) IN PUERTO RICO

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U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine[2],[3]

In Puerto Rico the West Indian blister mite constitutes one of the major cotton pests. In 1936 a few fields were completely destroyed and many others were severely damaged as a result of the attack of this mite. Damage was found to be most severe in fields in which the attack began on the young growing plants. In such cases the development of fruiting forms may be entirely prevented.

Serious damage to cotton by this pest has been reported from several widely separated areas. In India Thakar and Desai (**1**) report that this mite was first recorded in the year 1900, as a pest of cotton at Surat, the damage being as much as 50 per cent, and that since that date it has caused serious injury to cotton almost annually. In the West Indies Ballou (**2**) reports that this mite first occurred as a cotton pest in 1903, in Montserrat, and that soon afterwards it was found attacking wild and cultivated cotton in all the other islands of the Leeward and Windward groups and appeared in Barbados in 1912. During a visit to the Virgin Islands in 1931, U. C. Loftin was informed by former cotton growers that the blister mite had been known as a cotton pest for many years and was one of the principal "diseases" against which the ordinance passed by the Colonial Council of St. Croix in 1911 regulating the dates of planting and cleaning of fields was directed. The date of its first occurrence as a cotton pest in Puerto Rico is unknown but its presence was established in 1920 when Quarantine No. 47 of the United States Federal Horticultural Board against this mite was promulgated. According to Rainwater (**3**), "This cotton pest was not known to occur in the United States prior to June 1932, when U. C. Loftin collected it from wild cotton at Key Largo, and from door-yard plantings of Sea Island cotton in Key West." It is not known to occur in any section of the United States except southern Florida.

[1] Order Acarina, family Eriophydae. Determined by H. E. Ewing.

[2] In cooperation with the Puerto Rico Experiment Station of the United States Department of Agriculture.

[3] These studies were made possible by funds allotted to this bureau during 1935–36 under Puerto Rico (sugar-processing) tax fund order No. 2.

In Puerto Rico the West Indian blister mite was found during 1935 and 1936 in all cotton-growing districts along the northern coast. In November 1936, late in the season, every field in this region was found heavily infested. In addition, a light infestation

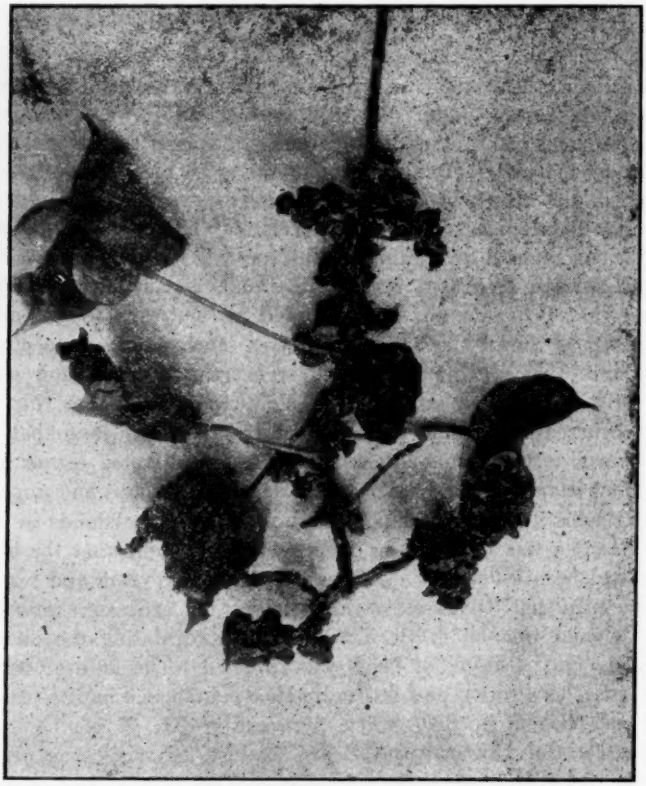

FIG. 1.—Young cotton plant showing characteristic injury by the West Indian blister mite (*Eriophyes gossypii* Banks). Lack of fruiting branches and forms, distorted and crumpled leaves, and distorted growth are very noticeable. Plant height, 16 inches. Isabela, P. R., May 16, 1936.

was found on cultivated cotton at Boquerón on the southern coast. In May 1936 wild cotton trees at Corozal, San Juan, and Naranjito were found heavily infested.

Nature of Injury.—Characteristic injury to cotton as a result of the feeding habits of the West Indian blister mite is shown in figure 1. This mite attacks all parts of the cotton plant except the roots. The invasion begins on the young fruiting buds which are located in the axils of the leaves. The external indication of attack is a distorted or crumpled appearance of the affected parts, which have a growth of fine, short, white hair. An extensive proliferation of hair, especially on the lower surface of the leaf, is also noted. On the leaves the mites are mostly found on the lower surface, sucking the plant juices from the outside, causing a chlorosis of the tissues on the upper and lower epidermis. The palisade cells of the affected leaves fail to develop their normal length, being about one-third the length of palisade cells not affected by gall formation. The small white blisters are evidently caused by the irritation set up by these mites and result in hypertrophy of the affected part. The most noticeable injuries to heavily infested plants are the crumpled leaves, distorted growth, and lack of fruiting branches and forms. The mites no doubt destroy the buds of these branches and forms, preventing their development. Later on small leaves develop where the fruiting branches normally form, and as a result many small leaves with short petioles are borne along the main stem. Severely affected squares do not open into normal flowers because the petals become so tightly bound together by overgrowth that they can not separate from one another. Abnormal shedding of the squares or young bolls was not noted as a result of mite attack.

Extent of injury.—In order to show the extent of injury caused to cotton plants by this pest, counts were made of the number of fruiting branches, squares, bolls, and blooms and the plant height on plants in each of three different groups. Since the infestation was very uneven and adjacent plants in the same row were affected to different degrees, plants were selected at random and divided into three groups according to the degree of infestation, namely, none or light, medium, and heavy. Counts of this nature were made on two different occasions, April 20 and May 6. The field contained about 3 acres. The distance between plants and number of plants per hill varied considerably but the sandy soil appeared to be uniform.

The results of counts made on the above-mentioned plots to determine the amount of damage to Sea Island cotton by this pest are shown in table 1. It will be noted that the number of fruiting

branches, squares, bolls, and blooms, and plant height varied inversely as the degree of infestation. Large differences in the number of fruiting branches, squares, bolls, and blooms per plant were especially noted between the heavily and lightly or noninfested plants. On April 20 the differences between the average number of fruiting branches and forms per plant on the heavily and the lightly or noninfested plants were as follows: Fruiting branches 7.81, squares 9.33, bolls 1.54, and blooms 0.25. The average difference in plant height on this date was 5.85 inches. The average number of fruiting branches and forms per plant on the medium infested plants was about one-half the number found on the lightly or noninfested plants. At this time, 100 plants were examined in each group.

On May 6 the differences between the average number of fruiting branches and forms per plant on the heavily and lightly or noninfested plants were as follows: Fruiting branches 6.98, squares 9.15, bolls 4.39, and blooms 0.44. The average difference in plant height was 5.44 inches. On this date the difference between the average number of bolls per plant on the heavily and lightly or noninfested plants had decidedly increased over that of the examination made on April 20. However, the average number of fruiting branches and forms per plant on the medium infested plants on this date was only slightly less than on the lightly or noninfested plants.

In order further to confirm the foregoing observations, similar counts were made in two adjacent fields. A plot of 100 plants was staked off in each field. The number of fruiting branches, squares, and bolls, and the plant height in each of these plots were recorded bimonthly from April 15 to July 10, 1936. At the beginning of these observations the infestation on one plot was heavy while on the other plot it was light. However, the infestation gradually increased in the latter plot, and by July 10 became rather heavy. Therefore the counts were discontinued on that date. Other than the difference in the degree of infestation of this mite on the two plots, all other factors appeared to be uniform. The results of these examinations are shown in table 2 and graphically illustrated in figures 2 and 3. It will be noted that large differences were found in the number of fruiting branches, squares, and bolls on the lightly and heavily infested plots. As shown in figure 2, the difference in the number of fruiting branches between these two plots progressively increased at each consecutive bimonthly examination. The average difference per plant between the number of fruiting branches on

TABLE 1.—RESULTS OF EXAMINATION TO DETERMINE DAMAGE CAUSED BY THE WEST INDIAN BLISTER MITE (*ERIOPHYES GOSSYPII*) TO SEA ISLAND COTTON, ISABELA, P. R., 1936

Degree of infestation	Average number of fruiting branches on—		Average number of squares on—		Average number of bolls on—		Average number of blooms on—		Average plant height (inches) on—		Number of plants examined on—	
	April 20	May 6	April 20	May 6	April 20	May 6	April 20	May 6	April 20	May 6	April 20	May 6
None or light	9.00	10.19	10.62	11.69	1.54	5.40	0.28	0.50	16.23	18.29	100	52
Medium	5.44	9.29	7.45	11.07	.14	3.21	.09	.48	13.45	18.06	100	75
Heavy	1.19	3.21	1.29	2.54	.00	1.01	.03	.06	10.38	12.85	100	100

the lightly and heavily infested plots was 3.12 and ranged from 1.69 on April 15 to 5.27 on June 24. All fruiting branches were counted on each plot whether it was bearing fruiting forms or not. If only the fruiting branches bearing forms had been counted on each plot, these differences would have been much greater.

TABLE 2.—RESULTS OF EXPERIMENT TO DETERMINE DAMAGE CAUSED BY THE WEST INDIAN BLISTER MITE (ERIOPHYES GOSSYPII) TO SEA ISLAND COTTON, ISABELA, P. R., 1936

Date examined	Average number [1] of fruiting branches on—		Average number [1] of squares on—		Average number [1] of bolls on—		Average plant height (inches)	
	Lightly infested plot	Heavily infested plot	Lightly infested plot	Heavily infested plot	Lightly infested plot	Heavily infested plot	Lightly infested plot	Heavily infested plot
April 15	4.33	2.64	5.83	3.53	0.09	0.01	9.72	9.72
May 6	6.74	4.30	5.96	4.15	3.01	1.36	14.32	13.65
May 19	8.15	5.46	4.76	2.89	5.12	2.03	17.39	15.53
June 8	10.38	6.86	5.75	1.82	6.73	2.37	22.68	21.44
June 24	12.74	7.47	5.93	4.87	7.90	2.45	26.27	24.04
July 10	.....	.....	4.80	7.40	10.50	3.19	.....	.....
Average	8.47	5.35	5.51	4.11	5.51	1.90	18.08	16.88

[1] 100 plants examined.

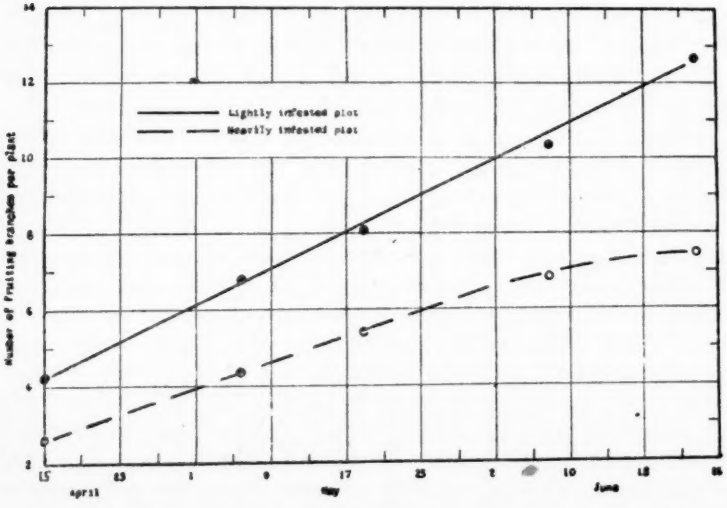

FIG. 2.—Average number of fruiting branches per plant on two plots, each plot containing 100 cotton plants with light and heavy infestation of the West Indian blister mite (*Eriophyes gossypii*) on each plot, Isabela, P. R., 1936.

Since these plots were also infested with the pink bollworm (*Pectinophora gossypiella* Saund.), the amount of seed cotton produced on each plot could not be used as a basis to estimate the damage caused by the West Indian blister mite. Therefore the best criterion was the number of bolls produced on each plot, since the pink bollworm causes but little if any shedding of the fruiting forms. As shown in figure 3, the difference in the number of bolls between the lightly and heavily infested plots also progressively increased at each consecutive bimonthly examination. The average difference per plant between the number of bolls in the lightly and heavily infested plots was 3.61 and ranged from 0.08 on April 15 to 7.31 on July 10.

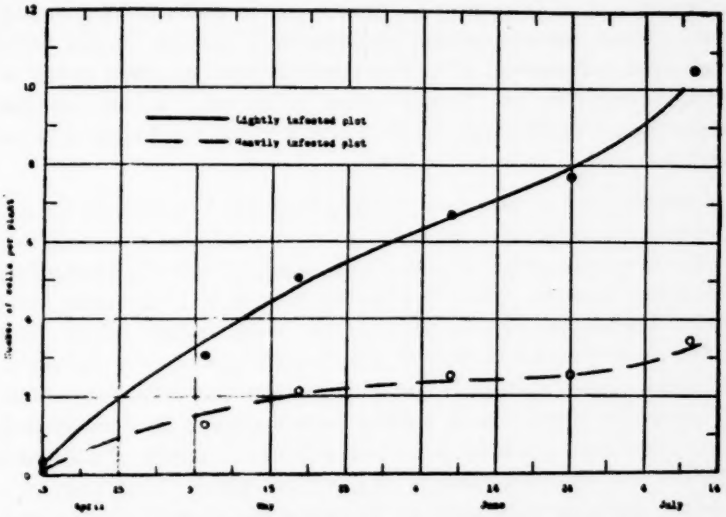

FIG. 3.—Average number of bolls per plant on two plots, each plot containing 100 cotton plants with light and heavy infestation of the West Indian blister mite (*Eriophyes gossypii*) on each plot, Isabela, P. R., 1936.

The average ratio of the number of squares on the two plots was 1 : 1.3+. The number of squares on the lightly infested plot was greater than on the heavily infested plot from April 15 to July 1, while the examination on July 10 showed the reverse to be true.

There is no doubt that the mites on the lightly infested plot caused considerable injury and consequently there was less difference in the number of fruiting branches and forms between these two

plots than would have been found if this plot had not become infested.

Carry-over and control.—So far as is known, cotton is the only host plant of the West Indian blister mite. In Puerto Rico cotton grows throughout the year and usually green plants that have not been destroyed or that have put out volunteer growth are present around the fields. Observations indicate that there is no hibernation period and that the mites continue to develop on these plants and spread to new plantings. In a field of young cotton at Isabela, on April 15, 1936, a heavy mite infestation was observed which had evidently spread from the new growth on old stalks in an adjacent field. These factors indicate that thorough cleaning of old fields and strict enforcement of a closed season when no green cotton is present would be an effective means of control. Wilson (**4**) has stated that a closed season of from 2 to 4 weeks is sufficient if properly enforced.

Blister mites of the genus Eriophyes on other malvaceous plants.—Blister mites of the genus *Eriophyes*[1] were found attacking two different species of malvaceous plants, namely, *Bastardia viscosa* and *Malachra capitata*. Since the blisters formed by these mites were quite similar to those made by the West Indian blister mite (*Eriophyes gossypii* Banks), it was deemed important to determine if these species were the same and would attack cultivated cotton. Twenty-four cotton plants, bearing mature green bolls, were divided into three lots containing eight plants in each. Leaves of *Bastardia viscosa* and *Malachra capitata* (*Malva*) and cotton (*Gossypium* sp.), heavily infested with mites of the genus *Eriophyes,* were fastened paper clips on the leaves of normal cotton plants. Only the transfers from cotton to cotton were successful, all the plants of this group becoming infested. This experiment was repeated with six young cotton plants, 10 inches in height, in each group. Again all the transfers from cotton to cotton were successful, and only these. These results show that the mites of the genus *Eriophyes* found on *Bastardia viscosa* and *Malachra capitata* in Puerto Rico will not attack cultivated cotton.

[1] Determined by H. E. Ewing of the Bureau of Entomology and Plant Quarantine.

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NEW OR LITTLE-KNOWN SPECIES OF WEST INDIAN TIPULIDAE (DIPTERA). II.

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The first part under this general title was published in the JOURNAL OF THE DEPARTMENT OF AGRICULTURE OF PUERTO RICO, vol. XX, No. 4, October, 1936, pages 877–882. In the present instalment, I wish to describe some interesting material collected in Puerto Rico by Messrs. Julio García-Díaz, James G. Needham and Mortimer D. Leonard, and a second rich series taken in Oriente, Cuba, by Messrs. Julián Acuña, Lawrence C. Bruner and L. Scaramuzza. The types of all the novelties are preserved in my collection of crane-flies through the friendly interest of the various collectors.

Dolichopeza (Megistomastix) acutiloba sp.n.

General coloration brown, the praescutum with four paler stripes; antennae with inconspicuous pubescence that is much shorter than the scattered, unilaterally arranged verticils; macrotrichia of wing-cells abundant; abdominal segments bicolorous, the bases of the segments brown, the posterior rings yellow; subterminal segments and hypopygium dark; male hypopygium with apex of each tergal lobe terminating in an acute spine; beak of inner dististyle relatively slender.

Male.—Length 7–8 mm.; wing 6.5–7.5 mm.

Female.—Length about 9 mm.; wing about 9 mm.

Described from alcoholic specimens.

Frontal prolongation of head pale brown; palpi brown, the outer segments slightly paler. Antennae brownish black, the pedicel yellow; flagellar segments broken beyond the third, but when entire the organ must be as long as, or longer than, the entire body; flagellar segments with scattered elongate verticils, unilaterally distributed, together with a very short, inconspicuous pubescence. Head brown, the front and orbits more brightened.

Pronotum brown. Mesonotal praescutum brown, with four paler stripes that are very poorly defined against the ground; scutal lobes a little darker than the median area; scutellum and postnotum brown. Pleura obscure yellow, indistinctly variegated with darker, especially on the anepisternum and ventral sternopleurite. Halteres dusky, the knobs whitened. Legs with the coxae brown; trochanters yellow; remainder of legs brown. Wings brownish gray; stigma oval, darker brown; veins brown. Macrotrichia of cells abundant, involving the outer ends of cells *R*, *M*, *Cu* and *1st A*, besides the cells beyond the cord. Venation: Petiole of cell M_1 a little shorter than *m*. The allotype female has cell M_1 very short-petiolate to nearly sessile.

Abdominal segments bicolorous, the bases brown, the posterior rings broadly yellow, the amount of the latter decreasing on the outer segments; outermost segments and hypopygium uniformly darkened. Male hypopygium (Fig. 6) with each lateral lobe of the tergite, *9t*, produced into an acute darkened spine; median area of tergite moderately produced. Outer dististyle, *od*, shallowly and unequally bifid, with a flattened glabrous lobule at base. Inner dististyle, *id*, with apical beak slender, pale.

Habitat.—Puerto Rico.

Holotype, ♂, El Yunque trail, Km. 1.3, June 11, 1935 (García-Díaz); Collector's No. 1200. Allotype, ♀, Picnic Grounds, Luquillo Mountains, June 7, 1935 (García-Díaz); No. 1082. Paratopotypes, 2 ♂ ♂, with the type, No. 1158, June 10, 1935; No. 1787, same date; paratype, 1 ♀, Luquillo Mountains, No. 46, June 10, 1935 (García-Díaz); No. 1182.

Dolichopeza (*Megistomastix*) *acutiloba* is most nearly related to *D.* (*M.*) *obtusiloba* sp.n., in the short, inconspicuous pubescence of the male antennae. The two species are most readily told from one another by the structure of the male hypopygium, especially the lateral lobes of the ninth tergite. The paratype female (No. 1182) has the petiole of cell M_1 unusually long, considerably exceeding *m*, and with a distinct darkened cloud on the anterior cord. It may pertain to a different species.

Dolichopeza (Megistomastix) obtusiloba sp.n.

Male.—Length about 7.5 mm.; wing 8 mm.

Described from alcoholic specimens.

Characters very similar to those of *acutiloba* sp. n., differing especially in the structure of the male hypopygium. Pubescence of flagellar segments pale, a trifle longer and more erect than in *acutiloba* but still less than a fifth as long as the conspicuous erect black verticils. Thoracic pattern much as in *acutiloba*. Wings with unusually abundant macrotrichia, which include nearly the outer two-thirds of cell *R* and the outer end of cell *2nd A*, as well as being very abundant in all outer cells. Venation: Union of R_1 and R_2 angulated and, in cases, with a spur of R_1+_2 persisting beyond the point of their union. Abdomen bicolorous, as in *acutiloba*, the pattern persisting to the outer segments; hypopygium pale. Male hypopygium (Fig. 7) with the lateral arms of tergite, *9t*, relatively long and conspicuous, at ends a little expanded into a head and provided with blackened spinous setae; median area of tergite strongly produced. Outer dististyle, *od*, deeply bifid, the inner arm very strongly capitate and set with abundant short dark setae; outer arm clavate, clothed with much longer setae. Inner dististyle, *id*, with the apical beak very stout; lobe at its base darkened.

Habitat.—Puerto Rico.

Holotype, ♂, El Yunque trail, Km. 1.3, July 27, 1935 (García-

Díaz); Collector's No. 1477. Paratopotypes, 1 ♂, Luquillo Mountains, west of swimming pool, November 18, 1935 (Needham & García-Díaz); No. 25; 1 ♂, Trout's Creek No. 1, Luquillo Mountains, June 9, 1935 (García-Díaz), No. 1122.

Dolichopeza (Megistomastix) vittinervis sp.n.

Antennae black throughout; mesonotal praescutum dark brown, with three grayish stripes, the broad median vitta vaguely divided by a dusky median line; pleura brownish gray, variegated with obscure yellow on the dorsal sternopleurite, ventral pteropleurite and meral region; knobs of halteres weakly infuscated; wings tinged with dusky; cells *C* and *Sc* brown, cord and veins *Cu* and *2nd A* seamed with brown; abundant, dark-colored macrotrichia in cells R_1 to M_4, inclusive, not reaching the cord of wing and not including cells *Cu* or *1st A*; *m* subequal to the petiole of cell M_1.

Female.—Length about 7.5 mm.; wing 8 mm.

Frontal prolongation of head dark grayish brown; palpi brownish black. Antennae black, only the pedicel a very little paler; basal flagellar segments of moderate length, with very short, delicate setulae and scattered longer verticils; outer segments shorter. Head brownish gray.

Mesonotal praescutum with the ground-color dark brown, with three grayish stripes, the median one broad, vaguely divided by a dusky median line; scutum with median area clear gray, the lobes more infuscated; scutellum and mediotergite clearer gray. Pleura chiefly brownish gray, variegated by an obscure yellow on the dorsal sternopleurite, pteropleurite and meral region but not forming a distinct longitudinal stripe; dorsopleural membrane light brown. Halteres pale, the knobs weakly infuscated. Legs with the coxae brownish gray; trochanters yellow; femora obscure brownish yellow, the tips narrowly darker; tibiae and tarsi infuscated. Wings (Fig. 1) with a strong dusky tinge, cells *C* and *Sc* brown; stigma and relatively conspicuous seams on anterior cord, posterior cord, and veins *Cu* and *2nd A* darker brown; veins and macrotrichia dark brown, conspicuous. Macrotrichia abundant in cells R_1 (stigma), R_2, R_3, R_4, M_1, *2nd* M_2, M_3, and M_4, not attaining the bases of the cells and not crossing basad of cord (position of trichia shown in figure by stippled dots); no trichia in cells *Cu* or *1st A*. Venation: R_1+_2 represented only by a tiny spur; *m* arcuated at near midlength, subequal to the petiole of cell M_1; M_3+_4 short, with *m-cu* at its fork.

Abdomen badly discolored by eggs within body; tergites chiefly light brown; cerci appearing as strongly compressed blades, their tips obtuse; hypovalvae very reduced.

Habitat.—Cuba (Oriente).

Holotype, ♀, Loma del Gato, Sierra del Cobre, altitude 2600–3325 feet, September 25–30, 1935 (Acuña, Bruner and Scaramuzza).

Dolichopeza (*Megistomastix*) *vittinervis* is quite distinct from the other species of the subgenus so far made known. It is apparently closer to the Puerto Rican species than it is to *D.* (*M.*) *cubensis* (Alexander) of western Cuba. The darkened antennae, pattern of

praescutum and wings, and the restriction of the very conspicuous wing-trichia provide good characters for the separation of the species.

Limonia (Rhipidia) tetraleuca sp.n.

General coloration yellow, variegated by brown; antennae brown, with four subterminal segments white; knobs of halteres variegated with white; posterior tarsi with three subterminal segments light yellow; wings cream-colored, the posterior cells darker; a relatively heavy darker brown costal pattern, the areas at origin of *Rs* and fork of *Sc* disconnected; wing-tip and axilla pale; basal abdominal segments whitened, the succeeding tergites with a brown median vitta.

Female.—Length about 7.5 mm.; wing 6.7 mm.

Described from the alcoholic type.

Rostrum black, the labial palpi paler; maxillary palpi black throughout. Antennae black, with segments ten to thirteen, inclusive, abruptly white; pedicels of the intermediate flagellar segments a little paler than those of the more basal ones; flagellar segments moderately produced, with conspicuous glabrous apical pedicels that become more elongate and slender on outer segments; terminal segment nearly as long as the preceding two taken together, its distal third narrowed. Head dark brown.

Pronotum dark medially, paler on sides. Mesonotal praescutum with an irregular dark pattern, the median stripe broad and entire on posterior half, interrupted and reduced to a capillary median vitta on anterior half, at cephalic border continuous with a narrowly darkened border; the latter area at its outer end has a sinuous broken stripe extending backward to the suture, roughly paralleling the median vitta, as described; scutum pale medially, the inner margin of each lobe entirely traversed by a dark brown stripe that extends to the chiefly darkened scutellum; mediotergite dark brown, with a conspicuous pale spot at each antero-lateral portion. Pleura chiefly pale, traversed by two longitudinal brown stripes, the more dorsal one much wider, extending from the propleura to beneath the abdomen. Halteres variegated, the base of stem yellow, the distal half black; knob black, extensively variegated with whitish. Legs with the coxae chiefly pale, traversed by the ventral pleural stripe; trochanters pale; remainder of legs dark brown, the posterior tarsi with segments two to four, inclusive, entirely light yellow. Wings with the cephalic half cream-colored, the posterior portion more darkened; anterior border variegated by about six large darker areas, the fourth (origin of *Rs*) and fifth (fork of *Sc*) disconnected; a narrow subterminal darkened fascia; wing-tip, in cells R_2 to *2nd* M_2, inclusive, pale; cord and outer end of cell *1st* M_2 narrowly darkened; axilla, in both anal cells, conspicuously white; veins brown, *Cu* yellow. Venation: Sc_1 ending shortly beyond midlength of *Rs*, Sc_2 at its tip; cell *1st* M_2 relatively long, its inner end strongly arcuated, with *m-cu* at fork of *M*.

Abdomen with the first segment and base of the second pale, the remaining tergites conspicuously darkened medially, narrowly pale on sides; darkened area narrowed behind, the pale borders correspondingly widened; sternites yellow. Ovipositor with the cerci small and weak, darkened, not extending caudad beyond the tips of the hypovalvae.

Habitat.—Puerto Rico.

Holotype, ♀, El Yunque trail, Km. 1.3, July 7, 1935 (García-Díaz); Collector's No. 1419–43–35.

The present fly is most nearly allied to *Limonia* (*Rhipidia*) *subcostalis* Alexander (Central America), differing especially in the pattern of the thoracic dorsum, abdomen and antennae. I had earlier (Dept. Sci. & Agr. Jamaica, Ent. Bull. 4 : 21–22; 1929) reported *subcostalis* from Jamaica, but it now appears more probable that the latter material represents a still different species. It is unfortunate that the males of several of these forms are still unknown.

Shannonomyia scaramuzzai sp.n.

General coloration dark brown, the pronotum and lateral pretergites ashy-gray; legs brownish yellow, the terminal tarsal segments darker; wings almost uniformly tinged with gray, the stigma pale brown; R_3 oblique, nearly twice R_{1+2}; R_2 subequal to R_{2+3}; cell *1st* M_2 closed; abdomen dark brown; hypopygium obscure brownish yellow.

Male.—Length about 4–4.2 mm.; wing 3.8–4 mm.

Female.—Length about 5.5–6 mm.; wing 4.5–4.8 mm.

Rostrum and palpi black. Antennae brown to dark brown, the scape more or less pruinose; flagellar segments subglobular to short-oval, the outer ones a trifle longer; verticils about twice the length of the segments. Head dark grayish brown.

Pronotum light ashy-gray, the coloration continued caudad on the lateral pretergites to the wing-root. Mesonotum uniformly dark brown, the praescutum unstriped. Pleura dark brown, sparsely pruinose. Halteres pale to slightly dusky, the knobs slightly more infuscated. Legs with the coxae and trochanters obscure yellow; remainder of legs brownish yellow, the terminal tarsal segments darker. Wings (Fig. 2) almost uniformly tinged with gray; stigma oval, pale brown, bisected by R_2; veins pale brown. Macrotrichia of veins very variable, in cases with numerous trichia on veins beyond cord, including a series of about a dozen on R_3, in other specimens R_{2+3+4}, R_{3+4} and R_3 without trichia. Venation: Sc_1 ending opposite midlength of *Rs*, Sc_2 at its tip; *Rs* angulated to weak-spurred at origin; R_2 subequal to R_{3+4}; R_3 oblique, nearly twice R_{1+2}; cell *1st* M_2 closed, exceeding in length vein M_4 beyond it; *m-cu* about two-thirds its length beyond fork of *M*.

Abdomen dark brown; hypopygium obscure brownish yellow.

Habitat.—Cuba (Oriente).

Holotype, ♀, Loma del Gato, Sierra del Cobre, altitude 2600–3325 feet, September 25–30, 1935 (Acuña, Bruner and Scaramuzza). Allotopotype, ♀. Paratopotypes, 1 ♂, 1 ♀; paratypes, several of both sexes, Pico Turquino, Sierra Maestra, altitude 3750 feet, June 12, 1936, at light (Acuña).

I take much pleasure in naming this fly in honor of Mr. L. Scaramuzza, who collected part of the type series. The fly is amply

distinct from the other Antillean species so far made known. It differs from *brevicula* Alexander and *mesophragma* Alexander, in the venation and in the virtually unmarked wings. In the latter regard it comes closer to *triangularis* Alexander, of Puerto Rico, which has cell M_2 of the wings open.

Gnophomyia (Gnophomyia) diazi sp.n.

Size small (wing, ♀, 4.7 mm.); general coloration black, including antennae, halteres and legs; wings nearly hyaline, with conspicuous black veins; R_{2+3+4} very strongly arcuated, nearly erect; cerci with setae to extreme tips.

Female.—Length about 5 mm.; wing 4.7 mm.

Described from the alcoholic type.

Head and appendages black; flagellar segments of antennae oval, the verticils subequal in length to the segments.

Thorax and appendages black. Wings (Fig. 3) nearly hyaline; stigma faintly indicated as a cloud beyond R_3; veins black, conspicuous. Venation: R_{2+3+4} very strongly arcuated, nearly erect; R_2 subequal to R_{3+4}; R_1 close to R_{1+2}, slightly upcurved at its tip; cell R_3 at margin wider than cell R_2; cell *1st* M_2 narrowed at proximal end; *m-cu* about one-third its length before fork of *M*.

Abdomen black; terminal segments narrowed, but not as markedly so as in *arcuata;* cerci with the tips truncated, provided with setae to extreme ends.

Habitat.—Puerto Rico.

Holotype, ♀, Luquillo Mountains, Km. 11.8, Lot 46, June 7, 1935, at light (García-Díaz); Collector's No. 1028–38–35.

I take unusual pleasure in dedicating this species in honor of the collector of the rich series of Puerto Rican Tipulidae discussed in this report. The only related species so far described is the larger *Gnophomyia arcuata* Alexander (British Guiana), which, besides its major size, differs in the more produced cerci and genital segment, and in slight details of venation and trichiation of the veins. The discovery of a species of *Gnophomyia* in the Greater Antilles is of unusual interest.

Gonomyia (Lipophleps) monacantha sp.n.

Male.—Length about 4–4.5 mm.; wing 3.2–4 mm.

Female.—Length about 5.5–6 mm.; wing 4–4.5 mm.

Belongs to the *cinerea* group; closely allied to *helophila* Alexander, differing chiefly in the structure of the male hypopygium, notably of the outer dististyle.

The fly has been adequately described and figured under the name *helophila* Alexander (Journ. Dept. Agr. Puerto Rico, 16 : 373, fig.

20; 1932), with which species it has been long confused in collections. The receipt of rather numerous specimens from Señor García-Díaz indicates that the Puerto Rican fly is distinct from *helophila,* which has a vast range on the American mainland, from Texas as far south as Peru. The structure of the male hypopygium of the two flies is shown by the accompanying figures. *G. (L.) monacantha* (Fig. 8) has a single powerful blackened spine on the inner margin of the outer dististyle. *G. (L.) helophila* (Fig. 9) has two such spines, both provided with microscopic spinulae.

The various figures of the male hypopygium of *helophila* hitherto provided (Ent. News, 27 : 345, fig. 3; 1916. Proc. Acad. Nat. Sci. Philadelphia for 1916, pl. 29, fig. 60; 1916) are inaccurate as regards the nature of the lobe of the outer dististyle.

Habitat.—Puerto Rico.

Holotype, ♂, Vieques Island, at light, September 25–27, 1931 (Leonard). Paratypes, 10 alcoholic ♂ ♀, Yúñez River, June 19, 1935, at light (García-Díaz); Nos. 1279, 1316; 1 ♀, Yúñez River, June 22, 1935, No. 1367; 1 ♀, Río Blanco, at light, March 6, 1935 (Needham & García-Díaz), No. 1784; 1 ♀, Lares, March 22, 1935 (Needham & García-Díaz), No. 722.

Gonomyia (Lipophleps) orthomera sp.n.

Belongs to the *manca* group; coloration yellow, the thorax variegated by brown; pleura weakly striped; male hypopygium with the dististyles terminal in position, the outer a long, slender, nearly straight spine, gradually narrowed to the acute tip; phallosome a single median structure, entirely pale, in slide mounts extending caudad to beyond the tip of the longest dististyle.

Male.—Length about 3.8–4 mm.; wing 2.8–3 mm.

Female.—Length about 4.5 mm.; wing 3.5 mm.

Described from alcoholic specimens.

Rostrum yellow; palpi dark brown. Antennae brownish black throughout, the flagellar segments with elongate verticils in both sexes, longer in the male. Head yellow, the center of vertex weakly darkened.

Pronotum yellow. Mesonotum yellow, the praescutum chiefly covered by three confluent brown stripes; median area of scutum yellow, the lobes brown; scutellum yellow; mediotergite yellow on sides, the central portion more darkened. Pleura yellow, with vague and poorly defined brown longitudinal stripes, the more dorsal occupying the propleura, anepisternum and ventral meron, becoming obsolete before the root of halteres. Halteres pale brown, the knobs whitened. Legs with the coxae pale brown; trochanters yellow; remainder of legs brown. Wings strongly tinged with brown, the stigma scarcely darker; veins pale. Venation: Sc_1 ending a distance before origin of *Rs* nearly equal to the length of the latter; branches of *Rs* strongly divergent near outer ends; *m-cu* before fork of *M*.

Abdominal tergites pale brown; sternites more yellowish; hypopygium yellow. Male hypopygium (Fig. 10) with the dististyles terminal in position; outer style, *od*, a long, nearly straight, simple spine that narrows to an acute point, the distal third darkened; inner style about one-half the length of the outer, weakly constricted near midlength. Phallosome, *p*, entirely pale, consisting of a long median structure, gradually narrowed outwardly, the apex slightly exceeding the tips of the longest dististyle.

Habitat.—Puerto Rico.

Holotype, ♂, Tanamá River, March 12, 1935, at light (Needham & García-Díaz), No. 545–21. Allotopotype, ♀. Paratopotypes, 2 ♀♀; 1 broken ♂, May 11, 1935 (García-Díaz), No. 882–21. Paratypes, 1 ♂, 1 ♀, Río Cidra, March 23, 1935 (Needham & García-Díaz), No. 819.

Gonomyia (*Lipophleps*) *orthomera* is entirely distinct from all previously described Neotropical members of the subgenus. By my key to the Puerto Rican species of *Lipophleps* (Journ. Dept. Agr. Puerto Rico, 16 : 371; 1932), the species runs to couplet 3, being very distinct from *bifiligera* Alexander, the male hypopygium of which has a single, entirely fleshy dististyle.

Toxorhina (Toxorhina) domingensis sp.n.

Mesonotum light ashy-gray, the praescutum with three brown stripes, the median one darker than the laterals; rostrum about four-fifths the length of wing; wings pale gray, the prearcular area pale yellow; veins pale brown, relatively distinct against the ground-color; male hypopygium with a slender darkened spine on mesal face of basistyle near tip; dististyle with the outer lobe roughly quadrate in outline; aedeagus lyriform, each arm relatively long, sinuous, drawn out into hair-like points.

Male.—Length, excluding rostrum, about 5.5 mm.; wing 5.2 mm.; rostrum alone 4.2 mm.

Rostrum about four-fifths as long as wing, pale brown, darker at outer end. Antennae with scape and pedicel dark brown; flagellum broken. Head brownish gray.

Mesonotal praescutum light ashy-gray, with three brown stripes, the median one darker and more clearly delimited; scutal lobes infuscated, the median area light gray; scutellum darkened basally, the posterior border pale; mediotergite brownish gray, paler laterally. Pleura light reddish brown, sparsely pruinose, with indications of darker longitudinal stripes, especially on the ventral sternopleurite. Halteres pale yellow, the knobs, excepting the tips, weakly infumed. Legs with the coxae light brown, paler at tips; trochanters yellow; remainder of legs pale brown, the tips of tibiae and the outer tarsal segments slightly darker. Wings (Fig. 4) with a pale gray tinge, the prearcular area pale yellow; veins pale brown, relatively distinct against the ground. Venation: Sc_1 ending opposite origin of *Rs*; R_1 very short, extending beyond the origin of *Rs* to a distance about equal to *r-m*; outer end of cell *1st* M_2 narrowed; *m* short, less than one-half *r-m*; *m-cu* about one-third its length before the fork of *M*.

Abdomen, including hypopygium, chiefly dark brown. Male hypopygium (Fig. 11) with the basistyle bearing a slender darkened spine on inner face near tip. Dististyle, *d*, with the outer lobe extensive, roughly quadrate in outline, the margin blackened, the inner or distal angle slightly more produced than the outer or more basal one. Arms of ædeagus *a*, elongate, each strongly sinuous to produce a lyriform appearance, their tips narrowed into hair-like points.

Habitat.—Santo Domingo.

Holotype, ♂, Sánchez, June 13–18, 1915. Paratopotype, Sex?, San Lorenzo, June 24–26, 1915.

In the structure of the male hypopygium, the present fly is closeest to *Toxorhina* (*Toxorhina*) *mendosa* Alexander (southern Brazil), differing in the details of venation and coloration, and in the structure of the hypopygium, especially of the aedeagus. The species that I have now determined as being *T.* (*T.*) *fragilis* Loew, with which the present fly was formerly confused in my collection Del., has a very distinct hypopygium, with the basistyle unarmed and the dististyle and aedeagus entirely different in structure.

Toxorhina (Toxorhina) violaceipennis sp.n.

Mesothorax deep orange; rostrum, legs and abdomen black; head gray; wings nearly hyaline, the membrane with unusually strong violaceous reflexions; veins black; *r-m* at near midlength of cell *1st* M_2.

Male.—Length, excluding rostrum, about 8 mm.; wing 7 mm.

Female.—Length, excluding rostrum, about 7.5–9 mm.; wing 5.3–7 mm.; rostrum about 3.8–4 mm.

Rostrum black, approximately one-half the length of remainder of body. Antennae black throughout; scape short. Head gray; anterior vertex relatively wide, a little less than three times the diameter of the pedicel.

Pronotum brownish black. Mesonotum deep orange, the praescutum weakly tinged with brown but without evident stripes. Pleura orange. Halteres brownish black. Legs with the fore coxae darkened, the remaining coxae and trochanters pale; remainder of legs black. Wings (Fig. 5) nearly hyaline, the membrane with unusually strong violaceous reflexions; veins black, very conspicuous against the ground. Venation: Sc_1 ending opposite origin of *Rs*, Sc_2 a little removed from tip; *r-m* at near midlength of cell *1st* M_2, the first and second sections of vein M_{1+2} subequal; cell *1st* M_2 closed; *m-cu* variable in position, from about one-fourth its length before the fork of *M* to this same distance beyond the fork; cell *2nd A* relatively wide.

Abdomen, including genital shield and valves of ovipositor, black. Male hypopygium black; mesal face of basistyle near apex with very abundant blackened setulose spines; apex of basistyle produced into a slender horn or spike. Dististyle blackened, produced into a slender apical beak and with a high outer crest, the entire outer margin microscopically roughened or serrulate. Branches of aedeagus short. Ninth tergite profoundly split along the midline and provided with an extensive triangular area that is densely set with very small, blackened setae and points.

Habitat.—Cuba (Oriente).

Holotype, ♂, Loma del Gato, Sierra del Cobre, altitude 2600–3325 feet, September 25–30, 1935 (Acuña, Bruner & Scaramuzza). Allotype, ♀, Pico Turquino, Sierra Maestra, altitude 3750 feet, June 12, 1936 (Acuña). Paratypes, 2 ♀♀, with the allotype.

Toxorhina (*Toxorhina*) *violaceipennis* is very different from all other described species in the Neotropical fauna, the orange mesothorax contrasting markedly with the black rostrum, legs, wing-veins and abdomen.

Explanation of Figures.

(Symbols: Male hypopygium,—*a*, aedeagus; *b*, basistyle; *d*, dististyle; *id*, inner dististyle; *md*, intermediate dististyle; *od*, outer dististyle; *p*, phallosome).

Figure 1. *Dolichopeza* (*Megistomastix*) *vittinervis* sp.n., venation.

Figure 2. *Shannonomyia scaramuzzai* sp.n., venation.

Figure 3. *Gnophomyia* (*Gnophomyia*) *diazi* sp.n., venation.

Figure 4. *Toxorhina* (*Toxorhina*) *domingensis* sp.n., venation.

Figure 5. *Toxorhina* (*Toxorhina*) *violaceipennis* sp.n., venation.

Figure 6. *Dolichopeza* (*Megistomastix*) *acutiloba* sp.n., male hypopygium.

Figure 7.—*Dolichopeza* (*Megistomastix*) *obtusiloba* sp.n., male hypopygium.

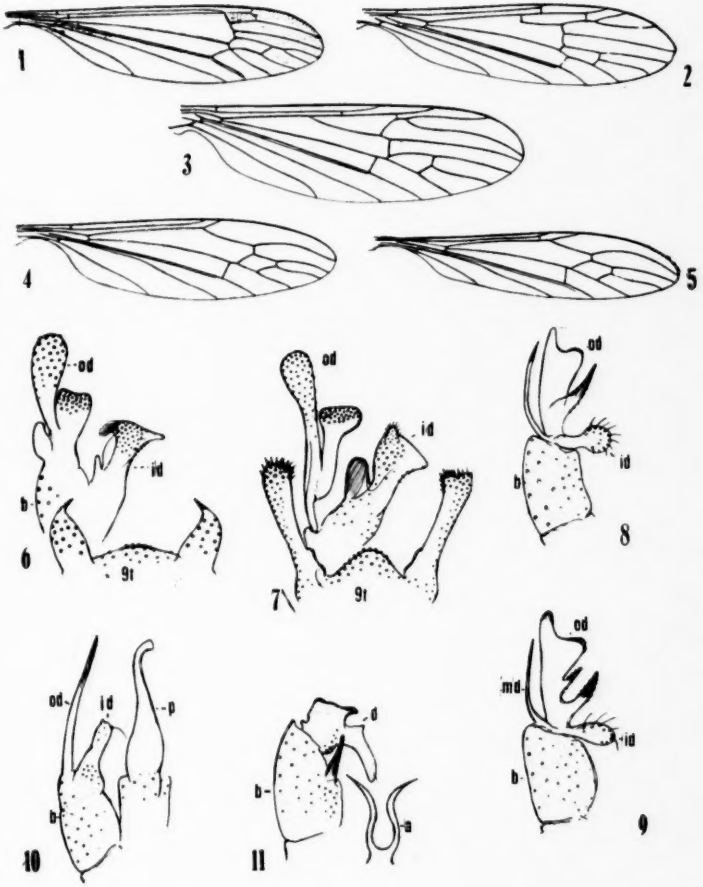
Figure 8. *Gonomyia* (*Lipophleps*) *monacantha* sp.n., male hypopygium.

Figure 9. *Gonomyia* (*Lipophleps*) *helophila* Alexander, male hypopygium.

Figure 10. *Gonomyia* (*Lipophleps*) *orthomera* sp.n., male hypopygium.

Figure 11. *Toxorhina* (*Toxorhina*) *domingensis* sp.n., male hypopygium.

PLATE VIII



STUDIES IN THE ENTOMOPHTHORACEAE

I. Observations on the genus *Conidiobolus*[1]

ARTHUR G. KEVORKIAN[2]

INTRODUCTION

While in Cuba during the summer of 1933 the writer encountered a fungus growing on living termites which had been placed in damp chambers for observation. Upon examination, the fungus proved to be a species of *Conidiobolus,* one of the Entomophthoraceae. This circumstance immediately aroused the writer's interest, since, so far as can be ascertained from the literature, no members of this genus have been reported as infesting termites. The fungus is of further interest since it was found to be identical with a saprophytic species described by Martin (**6**) as *Conidiobolus villosus,* which appeared as a contaminant on a plate of nutrient agar containing a bit of decaying wood harbouring a species of *Hypochnus.* Moreover, since the genus *Conidiobolus* is separated from *Empusa* and *Entomophthora,* among other reasons because of its saprophytic mode of existence, the writer was led to make further studies of the nature and affinities of the fungus in question in the hope that a comparison with other species of the Entomophthoraceae might help to elucidate the relationships of the various genera within the family. At the same time it was hoped to gain some understanding of the biology of the species concerned and to ascertain by experiment its ability to infect living insects, as well as to grow on various substrata.

MATERIALS AND METHODS

The Cuban fungus was isolated directly from termites of the genus *Nasutitermes*[3] inhabiting aerial termitaria by allowing spores

[1] Contribution from the Laboratories of Cryptogamic Botany, Harvard University, No. 148, and No. 10 from the Department of Botany and Plant Pathology, University of Puerto Rico, College of Agriculture.

[2] This investigation was undertaken while the writer was the holder of an Edwin F. Atkins Scholarship, stationed at the Harvard Botanical Gardens at Cienfuegos (Soledad), Cuba.

[3] The writer has recently collected from termites of the same genus in Cabo Rojo and Mayagüez, Puerto Rico, material which, when cultured, was found to have a life history similar to that of the Cuban fungus, although the former possesses slightly smaller spores (average diameter of smooth type 28–34 u). This is the first report of the occurrence of this fungus from the island.

from conidiophores on infected insects to be discharged against the lid of damp chambers and by transferring these spores to Blakeslee's agar. Subcultures of Martin's[2] type material of *Conidiobolus villosus* and an undetermined culture of *Conidiobolus*, isolated by Derx, from an unknown origin, as well as an unnamed species of Empusa described by Sawyer (**10**) were grown under similar conditions for comparison.

For the purpose of studying the life-cycle of these fungi, van Tieghem cells were for the most part employed; petri dishes proved most useful in studying the growth of the fungi on different media. Furthermore, in order to ascertain whether the fungi were truly saprophytic or facultative parasites, inoculation experiments were conducted. Petri dishes of the fungi were first allowed to grow luxuriantly and to sporulate abundantly, and then the insects were allowed to crawl over the surface of the cultures for varying periods of time, at the end of which the insects were removed to sterile petri dishes containing paper moistened in order to maintain and insure optimum conditions of humidity for the development of these fungi.

Observations

Since the Cuban strain, unlike the other members of the genus, was found to be parasitic on termites, it first became necessary to establish its identity by working out its morphology, development and life-cycle in pure culture. When placed on artificial media, the subspherical, to ovoid basally apiculate spore, sends out from any point on the periphery except the rounded apiculus, a short germ tube which may bear a secondary conidium (fig. 2, I) similar to the first but slightly smaller, or may elongate, branch, and produce extensive hyphae which later, by the appearance of cross-walls, form irregularly shaped hyphal bodies. Within the host, however, the mycelium very soon begins to break up into hyphal bodies which subsequently give rise to mycelia that penetrate the insect body and emerge as external conidiophores which later bear the smooth or primary conidia (fig. 1, E-F). These are discharged in a manner similar to that described by Martin (**6**) for *Conidiobolus villosus* and by Thaxter (**12**) for *Empusa* (*Triplosporium*) *Fresenii*. Some of the primary conidia may then produce capillary or villose outgrowths (fig. 1, G-H), usually densely covering the entire surface of the

[2] Martin's type strain from the Thaxter culture collection at the Farlow Herbarium; Derx strain from the Centraalbureau voor Schimmelcultures in Holland; Cuban strain from Harvard Botanical Gardens, Cienfuegos, Cuba; and *Empusa* sp. from Miss C. M. Jacobs of Hunter College, New York City.

spore as in *Delacroixia coronata*, Gallaud (**4**), fig. 1, E, or occasionally restricted to small areas of the spore surface (fig. 2, A) thus approaching *Empusa* (*Triplosporium*) *Fresenii* (Thaxter l. c.), *Entomopthora fumosa* Speare (**11**), and *Entomophthora pseudococci* Speare (**11**). Under favorable conditions, that is with an abundance of moisture, nutriment and warmth (70–75° F), the hair-like appendages may swell at their terminal extremities (fig. 2, C) and give rise to minute uninucleate piriform or subglobose conidia (fig. 2, D-G) within 36–48 hours after the villose spores have been discharged from the conidiophores.

The life-history and morphology of this Cuban fungus, as just described, show certain similarities to those of another member of the Entomophthoraceae namely, *Delacroixia coronata* (Cost.) Sacc. and Syd., agreeing not only in the size and shape of the conidia but also in the production of villose spores which in turn may bear minute conidia at the ends of the capillary projections. The fungus agrees also with *Conidiobolus villosus* except that, in Martin's (**6**) original description no mention was made of the small conidia. It should be noted, however, that Martin's description gives an excessive range of size for the conidia including some so small as to suggest that the latter had originated, unobserved, as micro-conidia. Furthermore, while studying the type culture of *C. villosus*, the writer was able to obtain micro-conidia under the conditions mentioned above. Martin (l. c., p. 314) states that "A few resting spores have been seen in which the hairs were slightly swollen at the tips. In one culture a very few of the resting spores were provided with distinctly conical, spine-like processes. Intermediate stages were present in all cases, and such aberrant spores seem to represent minor variations due to unknown causes." Had the spores been examined in a saturated atmosphere, it seems probable that the significance of the variations might have been evident, and that these aberrant spores would have been found to be proliferating into micro-conidia, the "conical, spine-like processes" representing the former point of attachment of these minute spores. Under unfavorable moisture conditions, that is, absence of water of condensation, the echinate conidia or "resting spores" become thick-walled and after a period of rest when transferred to a suitable substratum, do not produce the micro-conidia, but germinate by putting forth a germ tube similar to that described by Martin (l. c.)

Like Martin (**6**) and Gallaud (**4**), the writer was unsuccessful in all his attempts to secure the sexual phase of the fungus, even by contrasting the various strains in artificial culture. However the

appearance in the Cuban material of certain thick-walled structures closely resembling zygospores, needs further critical study to determine their true nature.

The presence of micro-conidia in *Conidiobolus villosus* not only indicates a general relationship of this fungus with members of Thaxter's (**12**) sub-genus *Triplosporium*, of *Empusa*, but also brings into question the status of the species. In 1897 Constantin (**3**) described *Boudierella coronata*, a fungus which he had isolated from the gills of *Psalliota campestris*, as a new genus of the Entomophthoraceae. This fungus, which is known only in the conidial stage, is characterized not only by the formation of villose conidia or "resting spores", but also by the production of micro-conidia as noted above. Later Saccardo and Sydow renamed the fungus *Delacroixia coronata* (Cost.) Sacc. and Sydow, since the former generic name had been preëmpted. In 1905 Gallaud (**4**) isolated the same fungus from orchid seeds, but since he only rarely obtained the "spores en couronne" of Costantin, he referred the material to the original author for identification.

Since *Delacroixia coronata* and *Conidiobolus villosus* are so similar in their life histories and morphological details, the writer feels that there is no necessity of maintainng the two names unless it is possible eventually to demonstrate differences in the sexual phases of the two genera. Furthermore since the genus *Delacroixia* was based only on the appearance of "spores en couronne" or micro-conidia, induced by an abundance of moisture as in *C. villosus*, the writer agrees with Lakon (**5**) that this is not a sound basis for establishing a new genus, since Thaxter (l. c.) had already shown that a somewhat similar proliferation takes place in the sub-genus *Triplosporium* of the genus *Empusa*.

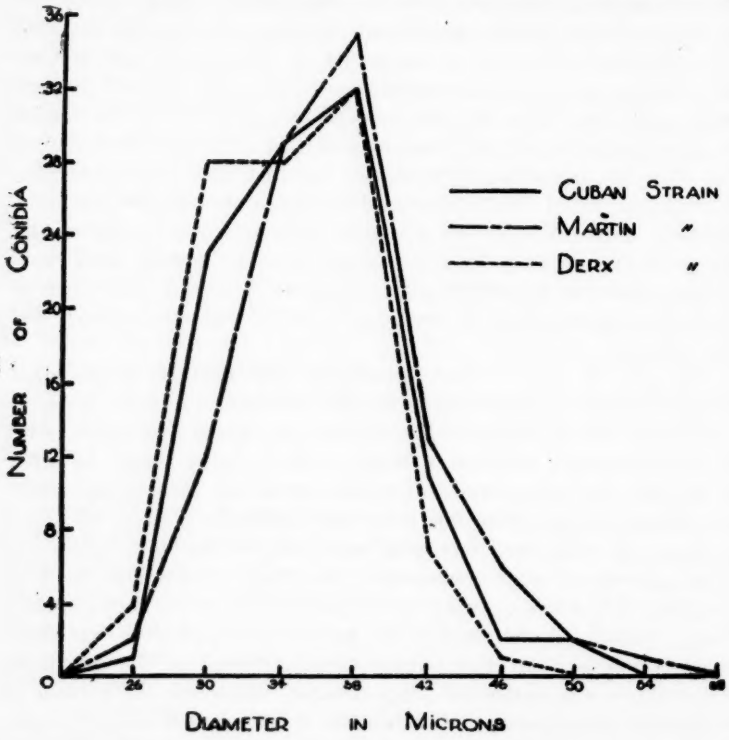
In view of the fact that *Conidiobolus* has been separated from *Entomophthora* and *Empusa*, primarily because of its saprophytic mode of life, experiments were undertaken to test the ability of the three strains of *C. villosus* to parasitize various insects. The writer, therefore, in triplicate series, exposed thirty-five termites and ten corn-borer larvae to infection by allowing them to crawl about on three sets of petri-dish cultures representing the three strains of the fungus that have been discussed above, and then placed the insects in damp chambers. This experiment showed that not only the Cuban strain isolated from termites but also the type material of *C. villosus* originally from rotten wood, was able to infect 60% of the termites within ten days, whereas in the case of the Derx strain whose source of isolation is not known, no infection took place

even at the end of twenty-one days. These results immediately suggested that there was a physiological difference which distinguished the latter strain from the other two. In contrast, only one corn-borer was killed by the Cuban strain after ten days, while the others remained free from infection even after a longer period of exposure. In a similar experiment however *Empusa* sp., attacked approximately 40% of the larvae within the same length of time and under similar environmental conditions. The present experiments with the Cuban fungus on termites, together with the earlier work of Costantin (**3**) who was successful in infecting *Musca domestica* with his organism, demonstrates the fact that these reputedly saprophytic fungi may live parasitically upon the proper hosts. Gallaud (**4**), however, using a variety of insects, was unable to find any evidence of parasitism, although when he placed dead cockroaches (Blatta) in contact with the spores he found that infection took place most readily in the muscles of the abdomen, thorax, and appendages.

Because the Derx culture behaved so differently from the other two in regard to parasitism it became necessary to study the morphological and physiological aspects of the various strains in order to determine what differences, if any, existed among them. In order to do this, the three strains of *Conidiobolus* and *Empusa* sp. were inoculated on the following substrata: Blakeslee's agar, sterilized carrots, egg yolk, swordfish, pork and liver. After a period of ten days, growth at room temperature, the Cuban strain and the type material of *C. villosus* were practically identical on the various media used. Growth of the Derx strain on egg yolk and liver was much more vigorous than the other strains, although on the remaining substrata it was noticeably more meager. Although the growth of *Empusa*, a recognized parasite, was less abundant on Blakeslee's agar, it was comparable in vigor with the development of *Conidiobolus* on the other substrata. It seems clear from the foregoing that the so-called saprophytic *Conidiobolus* is able to parasitize termites and conversely that the parasitic *Empusa* may be grown saprophytically on a variety of artificial media. Hence the existing differences between these two genera on this basis alone loses much of its weight.

Since differences in character of growth are so slight in all but the Derx strain of *Conidiobolus*, and since the organisms lack morphological distinctions, the writer made measurements of one hundred spores of the smooth type of each of the three strains in an endeavor to find a biometrical means of distinguishing them. The spores measured were produced on the same type of media and

under identical environmental conditions. It was noted that the spores of *Conidiobolus* from the three different localities were practically indistinguishable (Graph I), although those of the type strain



were 3 u. larger than the others. In view of our present knowledge of the fungi in question, it is doubtful if the Derx strain should be considered other than as a variant. Furthermore, the aforementioned organisms agree in nuclear condition as well as in their morphological and physiological behavior. Gallaud (**4**) has shown that *Delacroixia coronata* possesses multinucleate conidia while Martin (**6**) found the same to be true in *Conidiobolus villosus*. Moreover, the writer has confirmed Martin's findings not only in the type material but in the Cuban and Derx strains as well. In the genus *Empusa* a similar multinucleate condition has been shown in the conidia of a number of species investigated by Riddle (**9**), Cavara (**2**) and Olive (**8**).

The fact that *Conidiobolus villosus* and *Delacroixia coronata* have been shown to be similar morphologically, cytologically, and to a lesser extent physiologically, indicates that the confusion as to their taxonomy should be clarified.

Conclusions

As has already been stated, the genus *Delacroixia* was established to include a species of Entomophthoraceae with "spores en couronne". Gallaud, in 1905 encountered a fungus with spinose resting spores which Constantin identified as his *D. coronata* deviating from the type in only rarely producing the spores typical of the genus. Later, Martin (l. c.) described *Conidiobolus villosus* characterized by the villose appendages borne on the resting spores. The present writer has shown that these appendages are capable of giving rise to minute conidia similar to those of *D. coronata* and furthermore that the two fungi are similar morphologically and physiologically. There seems, therefore, no need of maintaining the later species, *C. villosus* as distinct.

Moreover, the genus *Conidiobolus,* founded by Brefeld (**1**) in 1884 was at that time thought to be readily distinguished from *Empusa* and *Entomophthora* by its saprophytic mode of existence. This, together with the fact that the strongly branched mycelium broke up into hyphal bodies early in the life cycle of the fungus, were the criteria upon which the genus was established. It has been shown elsewhere in this paper that at least certain strains of *C. villosus* may lead a parasitic mode of life in addition to a saprophytic one.

Furthermore other investigators, such as Speare (**11**), Molliard (**7**), and Sawyer (**10**), have shown that in the genera *Empusa* and *Entomophthora* a number of species which were considered obligate parasites, in reality are able to grow saprophytically. Undoubtedly other known species will be found to have a similar facultative saprophytism if investigators interested in growing them in artificial culture observe the cultural requirements revealed by Sawyer's work. The distinction supposed to exist between *Entomophthora, Empusa* and *Conidiobolus* is, therefore, lessened; as a matter of fact, material from artificial cultures of these genera, when examined under the microscope, cannot be distinguished morphologically with any degree of certainty until the resting spores appear. In addition, the microconidia in Thaxter's subgenus *Triplosporium* is another structural characteristic commonly found in certain species of each of the three

genera in question. In view of these facts, the writer believes that he is justified in making the new combination **Entomophthora coronata**[1] (Cost.) with the following as synonoms: *Boudierella Coronata* Cost., *Delacroixia coronata* (Cost.) Sacc. and Syd., and *Conodiobolus villosus* Martin.

In conclusion the writer wishes to express his indebtedness to Professor W. H. Weston, Jr., under whose direction this work was conducted; for his unstinted interest and kindly criticism, and to Doctor D. H. Linder for many helpful suggestions throughout the progress of this problem.

Summary

A comparative morphological and biometrical study on artificial media, has been made of strains of *Conidiobolus villosus* obtained from the Farlow Herbarium, the Centraalbureau voor Schimmelcultures, and isolated directly from termites in Cuba. Furthermore, infection experiments have shown that the fungus which has hitherto been considered a saprophyte may adapt itself to a parasitic habit, especially on termites. The Derx strain from Holland, in contrast to the others, appears to be strictly saprophytic. Moreover, in the life-history of the species in question an additional stage has been observed which consists of the production of minute conidia borne at the tips of the spiny appendages of the villose conidia or "resting spores". For these reasons a new combination, *Entomophthora coronata* (Cost.) has been made and *Delacroixia coronata* and *Conidiobolus villosus* have been reduced to synonomy.

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[1] The writer prefers to use the generic name *Entomophthora* rather than *Empusa* since the latter has been used earlier (1824) for a genus of orchids and is untenable as a genus of the Entomophthoraceae according to Article 65 of the International Rules of Botanical Nomenclature, which reads, "A name of a taxonomic group is illegitimate and must be rejected if it is a later homonym, that is if it duplicates a name previously and validly published for a group of the same rank based on a different type. Even if the earlier homonym is illegitimate, or is generally treated as a synonym on taxonomic grounds, the later homonym must be rejected."

Explanation of Text Figures

All drawings were made with the aid of a camera lucida, from material mounted in lactophenol. Each division of the scale represents 10u.

Text Figure No. 1.

A-D. Martin or type strain.

A and B. Smooth-walled conidia showing range in size. X 500.

C and D. "Resting spore", or echinulate conidia. X 500.

E-H. Cuban strain.

E and F. Smooth-walled conidia. X 500.

G and H. "Resting spore", or echinulate conidia. X 500.

Text Figure No. 2.

A-G. Martin or type strain.

A. "Resting spore" showing development of minute conidia only on portion of peripheral area. X 500.

B-G. Successive stages in the development of the minute conidia. X 500.

B. Villose appendage.

C. Appendage swollen at distal end, a primary step in the formation.

D-F. Further changes in development.

G. Minute conidium just prior to discharge.

H. J. Derx Strain.

H. "Resting spore" with minute conidia on portion of peripheral area as in Martin strain, Fig. A. X 500.

I. Primary conidium giving rise to secondary by means of a germ tube. X 500.

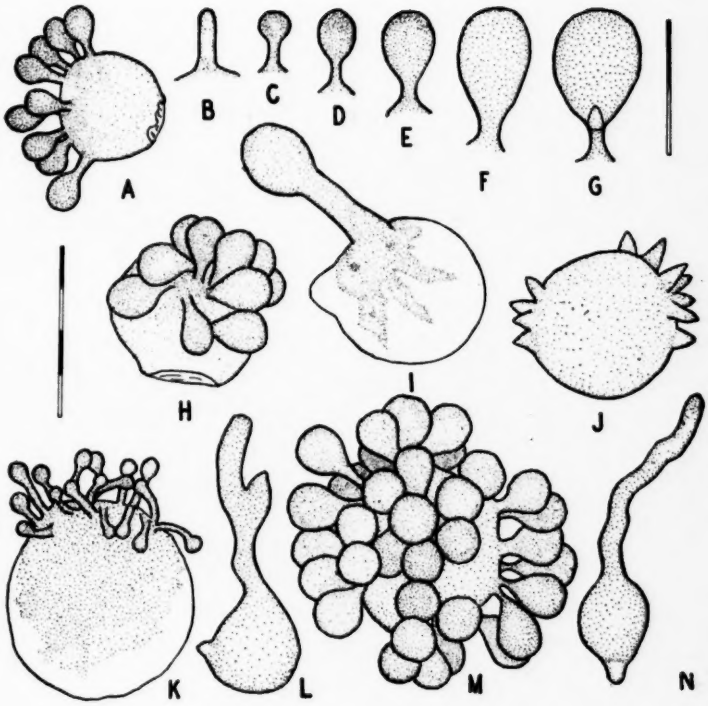
J. "Resting spore" showing minute conidia on only portion of periphery as in figures A and H. X 500.

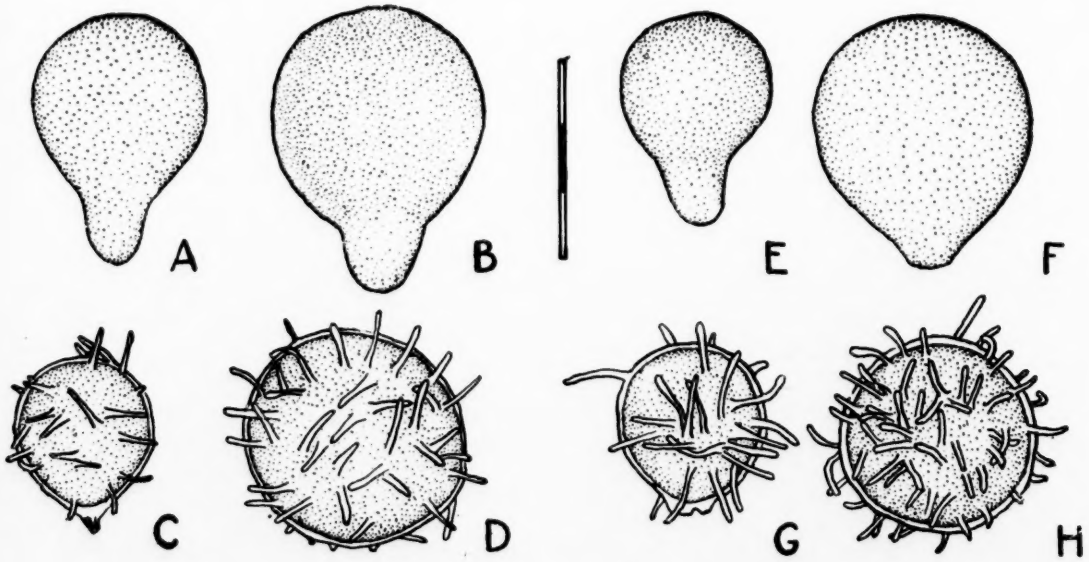
K. N. Cuban strain.

L and N. Germinating minute conidia. X 500.

M. "Resting spore" showing conidial development on entire peripheral area prior to septum formation and discharge. X 500.

PLATE IX





TYPE

CUBAN

PLATE X

PLATE XI

Photomicrograph showing villose type of conidium bearing the smaller microconidia at the apical extremities of the hair-like projections.

A COMPARATIVE STUDY OF THE STATISTICAL METHODS MOST COMMONLY USED IN AGRICULTURAL RESEARCH

By Bernardo G. Capó

Introduction

In statistical works the term *population* stands for a large group of individuals which possess one or more characteristics in common. These individuals may be persons, animals, numbers, leaves, etc., constituting respectively populations of persons, animals, numbers, leaves, etc.

The individuals themselves are different from one another and therefore the values which measure the intensity of any one of the characteristics common to all the individuals of a given population fluctuate between two limits: an upper and a lower one. These measurements, however, do not distribute themselves uniformly throughout all the range included between the limits, but on the other hand, their tendency is to distribute themselves in such a way that the number of values increase gradually from a very small number of them near the extremes to a very large number near the center of the distribution range.

The history of mathematical statistics has witnessed numerous attempts to explain by means of some mathematical formula or equation the exact way in which these values distribute themselves in naturally occurring populations. Among the curves represented by these equations the *normal curve* or *normal curve of error* has played a major role. Though inexact in itself, it is a close approximation to the exact distributions known as Binomial Law and Poisson Series, which in common with many other distribution curves, approach the normal curve as a limit, under certain conditions.

To graph the curve which represents any population of values normally distributed it is necessary to know the values of two *constants* or *statistics,* known as the *mean* and *standard deviation.*

The *mean* is equal to the sum of all the values divided by their total number, or in another way:

$$M = (X_1 + X_2 + X_3 + \text{.-----}) / n$$

where M is the mean of the values that constitute the population, X_1, X_2, X_3, etc., are the individual values; and n is the number of values.

For example the sale-prices of some grapefruit lots sold at public auction in New York were as follows: 2.50, 3.37, 3.62, 4.00, 3.87,

and 3.75. The mean of these sale-prices is found by adding them together and dividing their sum by 6, which gives as result $21.11/6 = 3.52$. This is of course, the mean of these six sale-prices, which is also an estimate of the true mean of the population of sale-prices represented by them.

The *standard deviation* or *standard error* of the individual values of a population is equal to the square root of the quotient obtained on dividing the sum of the squares of the differences between each value and the mean, by one less than the number of values, or in another way:

$$D = \sqrt{(X_1-M)^2 + (X_2-M)^2 + \text{.-----/ } (n-1)}$$

where D is the standard deviation of the values of the population and the other signs mean the same as in the previous formula.

Therefore, the estimate of the standard deviation of one of the sale-prices of the sale-price population represented by those of the preceding example is found as follows:

Values	Deviations from the mean (Differences between the values and the mean)	Squares of the Deviations
2.50	-1.02	1.0404
3.37	-0.15	0.0225
3.62	0.10	0.0100
4.00	0.48	0.2304
3.87	0.35	0.1225
3.75	0.23	0.0529
21.11 = Sum.		Sum of squares = 1.4787

Mean $= 21.11/6 = 3.52$ $\qquad 1.4787/5 = 0.2957$

Standard Deviation $= \sqrt{0.2957} = 0.54$.

Another way to find this estimate of the standard deviation which will be used on illustrating some of the statistical methods which will be described further on, is as follows:

	Values	Squares	
	2.50	6.2500	Correction = $(21.11)^2/6$ =
	3.37	11.3569	= 445.6321/6 = 74.2720
	3.62	13.1044	
	4.00	16.0000	
	3.87	14.9769	
	3.75	14.0625	Standard deviation = $\sqrt{0.2957}$ = 0.54
Sums	21.11	75.7507	
		- 74.2720	
		1.4787 / 5 = 0.2957	

The square of the standard deviation has been called by R. A. Fisher *variance* and since this term will be used frequently in the future, it is convenient to note its relation to the standard devia-

tion. In the preceding example the estimate of the variance of a single value of the population is equal to 0.2957.

In what follows it will be assumed that these estimates of the mean and standard deviation are equal to the real mean and standard deviation which could be calculated only from the values of all the individuals comprising the population; theoretically, an infinite number of values.

If twice the standard deviation of one of the values of the population under study is respectively added to and subtracted from the mean, there will be obtained two numbers which, if used as limits, will include between them about 95.45 per cent of the values which constitute the population. Therefore, the probability that any one of these values will fall by chance within these limits is of 95.45/100, where the total number of possibilities is unity.

Thus, then, in the previous example, if two times 0.54 or 1.08 is respectively added to and subtracted from 3.52, there will be obtained the quantities 4.60 and 2.44. If under similar conditions a large number of these sales were effected, it should be expected that 95.45 per cent of the sale-prices in these cases lie between 2.44 and 4.60, or the probability that any one of these sale-prices fall within these limits would be of 95.45/100.

In other words, 4.55 per cent of the values or sale-prices in sales made under similar conditions would be at prices lower than 2.44 or higher than 4.60, and of these, one-half would be at prices lower than 2.44. Thus, then, with this information one can deduct that of a large number of sales made under similar conditions, 2.28 percent will be made at prices lower than 2.44 and 97.72 per cent at prices higher than 2.44. It can also be deducted that under similar conditions the probability that a sale be made at a price higher than 2.44 against the probability that it be made at a price lower than 2.44 will be of 97.72 to 2.28 or of 43 to 1. Accentuating still more, it should be expected that 43 out of every 44 sales made under conditions similar to these will be made at prices higher than 2.44.

On the other hand, if it is desired to know the two limits (at equal distances from the mean) between which a certain percentage of the population is to be found, for example, 70 per cent, one must proceed as follows: If 70 per cent of the values fall within these limits, then 30 per cent of the values of the population will fall outside of them; or in other words, the deviations from the mean of 30 per cent of the values of the population will be larger than that which is sought, that is, than the deviation of the limits from the mean.

If one looks in the table of probabilities based on the normal curve, at the end of this article, it will be seen that in 30 per cent of the cases the deviations of the values from the mean exceeds 1.04 times the standard deviation or that the limits outside of which 30 per cent of the population lies are at distances from the mean equal to 1.04 times the standard deviation of the population. As in this case the standard deviation is 0.54, the limits will lie at distances from the mean equal to $1.04 \times 0.54 = 0.56$, and therefore they will be $3.52 - 0.56$ and $3.52 + 0.56$, or 2.96 and 4.08, respectively. In other words, 70 per cent of the population will lie between 2.96 and 4.08.

The relation which has given practicability to these formulas is the following fundamental postulate in all kinds of statistical methods: If a number of values are normally distributed around their mean with a standard deviation equal to D, then means of groups of n of these values will be distributed around their mean with a standard deviation equal to $D/\sqrt{n}$.

The standard deviation of the mean in the case of reference will then be $0.54/\sqrt{6} = 0.54/2.45 = 0.22$. This means that on subtracting from and adding respectively to the mean two times 0.22 or 0.44, the quantities 3.08 and 3.96 will be obtained, between which 95.45 per cent of the means of groups of 6 sales made under similar conditions lie. This postulate has given practicability to these formulas, not only for the fact that, as has been seen, the standard deviation of the mean of a number of values is smaller than the standard deviation of any one of them, and thus the value that another mean of the same number of values may have is fixed within narrower limits, but also because the mean represents the whole population.

The table of probabilities based on the normal curve, however, can be used only when the population is distributed normally and when the *exact* values of the mean and its standard deviation are known. However, as "Student" pointed out in 1908, with the necessarily limited number of values with which the research worker must work, be it in the laboratory or in the experimental field, it is impossible to determine exactly both the mean of the population which said values represent, and its standard deviation, being still more difficult to determine if the population is normally distributed or not. Therefore, if it is not possible to know exactly these facts, the use of the table of probabilities based on the normal curve becomes academic and loses all its utility.

For these conditions, however, "Student" developed another distribution curve which he called the distribution of "z", which

holds for the estimates of the mean and standard deviation as obtained from only a few values of the population, and, therefore, conclusions having a known degree of accuracy may be derived, even with some few values of observations, as in the case of a large part of the experiments performed by the investigators all over the world.

With these new tables, moreover, this can be done not only in those cases in which it is known that the means of groups of values distribute themselves normally with respect to their mean and standard deviation, but also in cases where the original values are distributed in a non-normal way, provided the departure from normality be not too wide. Therefore, the table of "z" has a very wide application, its use being of incalculable aid for the research workers in all branches of science.

R. A. Fisher has modified this table of "z" and obtained the distribution of $Z/\sqrt{n-1}$ which he has called "t". In Fisher's table of "t" the letter n means not the total number of values, but what he has called the *number of degrees of freedom.* This number of degrees of freedom is the number of values from a series of them which can be altered arbitrarily without altering their mean.

In the series of sale-prices the values have 5 degrees of freedom, since the total number of observations is 6, and if arbitrary values are assigned to 5 of them, the sixth value must have only one magnitude, if the mean is to remain equal.

With these new tables the problem of comparing the mean of the values which constitute a population with a certain fixed value and to determine the probabilities with which the mean will exceed said value is thus simplified. Thus, then, one can determine the probability with which a given fertilizer or cultivation treatment will produce yields that surpass a certain limit or with which the yield of a given variety of plants will exceed a given fixed value.

However, the object of the agricultural experiments in general is not to obtain varieties or treatments which will produce at least a certain fixed yield, but rather to determine which of any given number of these is the best under certain environmental conditions, or in case that there were two or more almost equal and better than the rest, which are these.

At present there are two general ways for making this selection in both of which the population whose mean is considered best, is compared successively with each of the other populations.

In the first of these ways one calculates the probability with which the difference between the means of the two treatments or

varieties to be compared is positive. This procedure is employed in what are known as Bessel's Method, Fisher's Method for the Analysis of Variance and Hayes Deviation from the Mean Method.

In the second of these ways one calculates the probability with which the mean of the differences between corresponding values of the two treatments or varieties to be compared is positive. This procedure is employed in what is known as "Student's" Method of Paired Results.

In what precedes the ways of estimating means and their standard deviations have been described. But now it has been seen that the estimates of the standard deviations of differences must be calculated also in the application of all those methods which calculate the probability with which the difference between the means is positive.

In order to do this the following relation is made use of: The standard deviation of the difference between any two means is equal to the square root of the difference between the sum of the variances of both means and twice the product of their standard deviations by the coefficient of correlation between the means they represent.

This is expressed mathematically as follows:

$$D_d = \sqrt{V_1 + V_2 \ -2D_1D_2C}$$

where D_d is the standard deviation of the difference between the means, V_1 is the variance of one of the means and D_1 its standard deviation, V_2 is the variance of the other mean and D_2 its standard deviation, and C is the coefficient of correlation between the populations which the said means represent.

The method can be used then only to compare populations whose coefficient of correlation can be estimated with a certain degree of accuracy, for it cannot be determined exactly, due to the same reasons which hold for the values of the means and their standard deviations.

The labor which is needed to calculate this coefficient of correlation, in addition to the fact that in order that it may be calculated the experiment must comply with certain requisites, has made that the majority of the investigators use modifications of this method, of which there are some. In fact, the differences between these methods consist precisely in the different ways of modifying the application of this formula. These modifications will therefore be taken up in connection with the descriptions of the methods.

Before proceeding with the detailed descriptions of the methods there is still one point to be taken up, which is as follows. In order

that uniform conclusions may be derived from the interpretation of the same data by different investigators it has been accepted to consider as a statistically significant difference, that difference which has a probability in favor of its being positive of not less than 21/22. Since this is the probability that should be used on making the interpretation of agricultural experiments the tables of "z" and "t" for this probability have been calculated and reproduced at the end of this article.

These preliminary considerations, which seemed to be necessary for the practical use of the different methods in use at present being finished, it is now time to describe the different methods in order.

Bessel's Method

This method, as has been already said, belongs to those methods in which one calculates the probability with which the difference between the means of two populations is positive, that is, with which one of the populations will be better than the other, as witnessed by the means of the characteristic under study.

In this method the formula for the standard deviation of a difference between two means is modified by discarding altogether the term which contains the coefficient of correlation converting it into:

$$D_d = \sqrt{V_1 + V_2}$$

In order that this modification be correct, it is necessary that the conditions under which the experiment which is going to be interpreted in this way be such that the value of C, or coefficient of correlation between the populations to be compared, be so small that the term $2D_1D_2C$ be negligible. Under these conditions one has to calculate the means of the two populations to be compared and their variances and apply this formula.

To approximate these conditions as much as possible, it is the custom to distribute by chance throughout all the experimental field the different replications or repetitions of the treatments to be compared.

The diagram which follows represents the plan of an experiment performed under the direction of Mr. Fernando Chardón at Aibonito, P. R. The object of the experiment was to determine which of the seven fertilizer treatments tested would help to produce more tobacco leaf in a certain variety of tobacco at that region and under the then existing climatic conditions. The size of the plots was 1/50 of a *cuerda* (1 cuerda is 0.97 of an acre) and the yields are in hundredweights per *cuerda*.

DIAGRAM No. 1

B 8.38	D 9.00	A 7.45	G 8.03	F 9.69	E 9.50	C 7.92
F 9.64	G 8.86	D 9.84	E 9.55	A 8.91	C 8.44	B 8.29
D 9.39	A 9.73	E 10.00	C 10.34	G 8.75	B 8.06	F 7.61
G 10.03	E 10.30	B 8.36	F 8.41	C 9.59	A 7.58	D 8.44
C 9.22	F 7.95	G 7.06	A 8.36	B 9.70	D 9.45	E 8.98
E 7.98	C 8.70	F 8.69	B 8.97	D 9.09	G 7.69	A 7.63
A 7.30	B 8.23	C 6.98	D 8.22	E 9.13	F 7.86	G 8.03

Even though the distribution was such that there should be a repetition of each treatment in each file and column of the experimental field, that is, in the form of a Latin Square, as the repetitions for each treatment were distributed throughout all the experimental field, and within most columns and files the treatments were distributed by chance, it is to be expected that the correlation should not be too high and that the method of the modified formula may have here application. As these same results are to be used to illustrate the application of all the methods, one can assume for the present that the distribution was done by chance and that the results obtained were as appear in the diagram.

The means, their variances and standard deviations are calculated as explained in the preceding pages:

Treatment A—

Values	*Squares*	
7.45	55.5025	
8.91	79.3881	Mean = 56.96/7 = 8.14
9.73	94.6729	Correction of the sum of squares = $(56.96)^2$
7.58	57.4564	= 3244.4416/7 = 463.4917
8.36	69.8896	Variance of one value = 4.9247/6 = 0.8208
7.63	58.2169	Variance of the mean = 0.8208/7 = 0.1173
7.30	53.2900	Standard deviation of the mean = $\sqrt{0.1173}$ = 0.34
56.96	468.4164	Yield of A = 8.14 ± 0.34
	−463.4917	
	4.9247	

In the same way these values are found for the other treatments. The yields of the different treatments in order as regards amount, are:

Treatment—E:	9.35 ± 0.29	Variance of the mean $= 0.0822$
Treatment—D:	9.06 ± 0.22	Variance of the mean $= 0.0468$
Treatment—C:	8.74 ± 0.45	Variance of the mean $= 0.1994$
Treatment—B:	8.56 ± 0.22	Variance of the mean $= 0.0483$
Treatment—F:	8.55 ± 0.32	Variance of the mean $= 0.1010$
Treatment—G:	8.35 ± 0.51	Variance of the mean $= 0.2628$
Treatment—A:	8.14 ± 0.34	Variance of the mean $= 0.1173$

As each one of the means of these treatments is based on 6 degrees of freedom there being 7 observations of each population, it is evident that the difference between any two of these means will be based on 12 degrees of freedom. Looking up in the table of "t" the ratio which corresponds to 12 degrees of freedom, for a probability of 21/22, one finds 1.83.

Now then, as the square root of the sum of the squares of two numbers must be greater than any one of the two numbers, and furthermore, as the difference between the means to be compared is to be compared with a number that is 1.83 times its standard deviation, it is evident that all the means of yields smaller than the largest but lying below it by not more than 1.83 times its standard deviation, will not give yields smaller than its yields in 21 cases out of 22.

Thus then, as the standard deviation of the mean 9.35 is 0.29, all the treatments whose means be less than 9.35 but more than $9.35 - 1.83 \times 0.29$ or $9.35 - 0.53 = 8.82$, will not be different in yield from treatment E, in at least 21 cases out of 22. That means that the method indicates preliminarily that treatment E gives not higher yields than treatment D in at least 95.45% of the cases, for the mean of the yield of D exceeds the inferior limit 8.82 already fixed.

The differences between the yields of treatment E and the other ones, are proved as follows as regards their statistical significance:

Between E and C:

Mean of E $=$	9.35	Variance of the mean of E $=$	0.0822
Mean of C $=$	8.74	Variance of the mean of C $=$	0.1944
Diff.	0.61	Variance of the diff.	$= 0.2766$

Standard deviation of the difference $= \sqrt{0.2766} = 0.52$

Amount which the difference must exceed to be significant

$$= 1.83(0.52) = 0.95$$

Since the difference does not exceed this limit, it is not significant.

In the same way are calculated the amounts to be exceeded by the differences between the mean of E and the means of B, F, G and A, concluding that treatment E is superior to treatments B, F and A.

Adding up, if one calculates the experiment under study by this method, that is, without making any correction for the error introduced on discarding the term which includes the coefficient of correlation in each comparison, one arrives at the conclusion that the treatments inferior to treatment E are treatments A, B and F and that there is no evidence as to statistically significant differences between treatment E and treatments D, C and G.

Note: There is a method which tries to eliminate the effects of soil heterogeneity by introducing check plots every three or four treatment plots. The fertility of the field is assumed to vary uniformly from one check plot to the other and the yields of the treated plots are then corrected by subtracting from each yield the respective yield which it would have produced if it were a check plot. The residues are then treated as above.

Once illustrated the preceding method, we will proceed to illustrate the method that uses the formula for the standard deviation of a difference without modifications of any sort. In this method, as has been already pointed out, one must calculate the coefficients of correlation between the different pairs of populations to be compared.

As the correlation of the yields is the result of the heterogeneity of the soil to the extent that the nearer two plots are from one another the larger will be the similarity between their autochthonous fertilities, and therefore, the larger the correlation between the yields of any pair of treatments applied in them, it is the custom when the said coefficient is to be used, to distribute the replications systematically throughout all the experimental ground in order that the replications of each treatment be within given distances from the respective replications of any other treatment at least in a major part of the replications.

To calculate the coefficient of correlation between the two populations or series, there must be known first of all with which value of one of the series each value of the other one is respectively related. In other words, the individual values of both populations must be related in some specific manner and this relation must be known in order to calculate said coefficient.

As our interest rests in presenting the most common methods of interpreting the results of the agricultural field experiments, and not the different ways of carrying into effect the application of these methods, an exposition of but one way of calculating the coefficient of correlation between two populations is made.

In the example which occupies our attention the related values of the populations to be compared are those which lie in the same file and in the same column, for if diagram No. 1 is observed, it will be seen that each value of one population is related in this form with two values of every other population.

The coefficient of correlation between two populations is found by making use of the following formula where C is the coefficient of correlation between the two populations "1" and "2".

$$C = \frac{S(xy)}{(n-1)\ d_1 d_2}$$

where the numerator is the sum of the products obtained on multiplying the respective deviations of the associated values of the two series from their respective means; n is the number of pairs of correlated values, and d_1 and d_2 are respectively the standard deviations of the individual values of both series.

If one allows that N be the number of observations in which each mean is based and D_1 and D_2 the standard deviations of said means, the preceding formula may be modified in this way:

$$C = \frac{S\ (xy)}{(n-1)\ d_1\ d_2\ N} = \frac{S\ (xy)}{(n-1)\ D_1 D_2\ N}$$
$$\sqrt{N}\ \sqrt{N}$$

The advantage of the use of this last formula is obtained on using it to modify the formula for the standard deviation of a difference in this way:

$$D_d = \sqrt{D_1^2 + D_2^2 - 2\,C D_1\,D_2}$$
$$= \sqrt{D_1^2 + D_2^2 - \frac{2\,D_1\,D_2}{(n-1)} \cdot \frac{S\,(xy)}{D_1\,D_2\,N}}$$
$$= \sqrt{D_1^2 + D_2^2 - \frac{2\,S\,(xy)}{(n-1)\,N}}$$

To apply then this formula to the comparison between the means of the two populations desired, one would need only to know the value of S(xy) between the said populations. That value between

the populations of yields of the treatments E and D is found as follows:

E Values	E Deviation from the mean x	D Values	D Deviation from the mean y	xy
9.50	0.15	9.00	−0.06	−0.0090
9.55	0.20	9.84	0.78	0.1560
10.00	0.65	9.39	0.33	0.2145
10.30	0.95	8.44	−0.62	−0.5890
8.98	−0.37	9.45	0.39	−0.1443
7.98	−1.37	9.09	0.03	−0.0411
9.13	−0.22	8.22	−0.84	0.1848
7.98	−1.37	9.39	0.33	−0.4521
10.30	0.95	9.00	−0.06	−0.0570
10.00	0.65	9.84	0.78	0.5070
9.55	0.20	8.22	−0.84	−0.1680
9.13	−0.22	9.09	0.03	−0.0066
9.50	0.15	9.45	0.39	0.0585
8.98	−0.37	8.44	−0.62	0.2294
130.88 / 14 = 9.35		126.86 / 14 = 9.06		S(xy) = −0.1169

As in this case the correlation was negative, without existing any apparent cause for such an event, one should disregard the term containing the coefficient of correlation, interpreting the results as previously done.

By this same process one finds that the value S(xy) between the populations corresponding to treatments E and C is equal to 0.9107. The standard deviations of the difference between the means 9.35 and 8.74, subject to their respective variances 0.0822 and 0.1994 is then

$$D_d = \sqrt{0.0822 + 0.1994 - 2(0.9107)\,/13(7)}$$
$$= \sqrt{0.2816 - 0.0200} = \sqrt{0.2616} = 0.51.$$

The amount which the difference between the means must exceed is now $1.83 \times 0.51 = 0.93$. As the difference is only 0.61, it is evident that it is not significant.

In the same way are calculated the standard deviations of the differences between the means of the yields of E on the one hand and those of B, F, G and A on the other, concluding that treatment E is superior to treatments B, F and A.

General Considerations

The two methods which precede, however, have been criticized as inefficient on pointing out the fact that in a large number of cases the standard deviations of the differences between the means are based on too few observations, and therefore, the amounts which said differences must exceed to be significant are too large.

This is due to the fact that the standard deviations of these differences have to be multiplied by relatively high values of "t" for these "t" values correspond to too small numbers of degrees of freedom.

The differences in yield of the different plots are due, in an experiment like the one which occupies our attention, to three main causes: first, to the difference in autochthonous fertility between the plots; second, to the difference of the treatments used; and third, to the fact that all the plants used in the experiment will be different and each will behave, of course, differently to its environment.

On finding the standard deviation of the difference between the means by using the formula used above, part of the sum of the variances of the means is caused by the heterogeneity of the soil and the other by the different way in which the plants behave to their environment. This sum of the variances is diminished by the term $2CD_1D_2$ that represents the effect of the heterogeneity of the soil, leaving a quantity which is due solely to the different behaviour of the plants with respect to their environment, errors in weighing the yields, etc., which are considered experimental or indeterminable errors. It is with respect to this variance that the assumption is made that said difference distributes itself in the required way to make use of the values appearing in the table of "t".

Fisher and Hayes have assumed that the variance due to the differences in yields of the plots treated in a different way, once corrected to eliminate all effects that will not be constitutional differences between the plants and other indeterminable errors, are equal or almost so, and that all these variances may be added together obtaining from their total sum a generalized variance for the means of the yields of the different treatments.

This is more exactly true in those cases in which the treatments or varieties to be compared in the experiment be not fundamentally different among them, that is, when the difference among the treatments be one of degree only and not fundamental. Even when the difference between the treatments were fundamental, there are cases in which the variances though not qual, would not at least differ by much.

As the generalized variance is obtained from the total number of observations, it is evident that it will be subject to a much larger number of degrees of freedom than the variances of the means obtained individually in each case. The value of "t" by which the

standard deviation corresponding to any difference between the means must be multiplied will be smaller, therefore, and any difference would have to exceed a smaller quantity in order to be significant. In this way these investigators have increased the number of observations available for the estimation of the standard deviation of any one of the populations to be compared.

Fisher's Analysis of the Variance Method, Hayes' Deviation from the Mean Method, and Bessel's Method (where the term $2CD_1D_2$ is dropped), are applied when the plots where the different treatments are to be located are selected by chance, in order that any repetition may fall by chance, anywhere within any section of the experimental field or of the whole field.

Fisher's Analysis of the Variance Method has three phases. The first one is known as the "Unrestricted Method", where the plots are distributed by chance throughout all the experimental field. Hayes' Deviation from the Mean Method is almost identical with this phase of the Analysis of Variance Method, differing from it only in that the standard deviation is expressed in percentage of yield, there being therefore, different standard deviations of the means of the treatments when they are calculated in terms of weight, while in Fisher's Unrestricted Method, the standard deviation is fixed without taking account of the differences in amounts of the means of the yields of the different treatments.

The second phase of the Analysis of the Variances Method is known as the "Method of Randomized Blocks". To apply this method the plots are distributed by chance within some blocks or sections in which the experimental field is divided such that within each block there may be one and only one application of each treatment.

The third phase is known as the "Method of Least Squares". This one differs from the preceding one in that instead of dividing the experimental field into blocks, it is divided into files and columns and the treatments are located in such a way that in each file and in each column there may be but one repetition of each treatment.

In a general way, Fisher's Analysis of the Variance Method postulates that the total variance of the observations of any experiment is due to various causes, and that it can be divided in accordance with these causes, assigning to each cause that intensity of the variance which corresponds to it.

In Fisher's Unrestricted Method, and Hayes' Deviation from the Mean Method it is assumed, and this has been mathematically proved

by "Student", that when it is assumed that the variabilities within the different treatments are equal, then the total sum of squares consists of the sum of squares between the treatments plus the sum of squares within the treatments.

The variation between the treatments is due precisely to the differences among them, for, being different, they will produce in general different yields.

The variation within the treatments is due to the differences in constitution of the plants that are used in the experiment and to the difference in autochthonous fertility of the plots where the repetitions of the same treatment are planted, to errors on weighing the crop, etc.

The manner of calculating the variances due to these causes is demonstrated in the explanation which follows:

Fisher's Unrestricted Analysis of the Variance Method

This method, as has been pointed out, attempts to reduce the quantity to be exceeded by the difference between two means of treatments compared in an experiment in order that it may be considered significant by means of a theoretical increase in the number of observations that may be used in its determination. Instead of calculating the standard deviation of the mean of the yields of the different replications of any treatment by using the observations in the plots of this treatment only, in this method the variances of the means of all the treatments in the experiment are averaged together and a generalized standard deviation which is used for all at a time is calculated.

Following may be found the calculations necessary for the interpretation of the results of the experiment which is occupying our attention, assuming, as in the illustration of the application of the modified Bessel's Method, that the different repetitions of the different treatments were located by chance throughout all the experimental field.

Taking diagram No. 1 as example, there are two ways of calculating the standard error or standard deviation due to experimental error. The variance from which the standard deviation is to be calculated is obtained by dividing by the proper number of degrees of freedom, the sums of the squares obtained either by adding the sums of squares due to error within the different treatments or by subtracting the sum of the squares between the treatments from

the total sum of squares. Both methods are illustrated in what follows:

To find the sum of squares due to error by adding the sums of squares within the different treatments.

These sums of squares within the different treatments are found just as was done in the method which uses the modified formula where the following sums of squares were found:

Sum of squares within treatment A	4.9247
Sum of squares within treatment B	2.0285
Sum of squares within treatment C	8.3745
Sum of squares within treatment D	1.9639
Sum of squares within treatment E	3.4505
Sum of squares within treatment F	4.2466
Sum of squares within treatment G	11.0361
Total sum of squares within the treatments	**36.0248**

The variance within each treatment is subject to 6 degrees of freedom for there are 7 observations and only the mean of each treatment is fixed. Thus, as there are 7 treatments, the total sum of squares within the treatments is subject to $7 \times 6 = 42$ degrees of freedom. The variance of any single value due to error will then be $36.0248/42 = 0.8577$.

To find the sum of squares due to error by difference between the total sum of squares and the sum of squares between treatments.

The total sum of squares is found by taking all the observations and finding the sum of squares by treating them as if they belonged to a single treatment, and one were to find the sum of squares within that treatment, thus:

Copying from page 11:

Treatment	Values	Sum of squares of the values
A	7.45, 8.91, 9.73, 7.58, 8.36, 7.63, 7.30	468.4164
B	8.38, 8.20, 8.06, 8.36, 9.70, 8.97, 8.23	514.6014
C	7.92, 8.44, 10.34, 9.59, 9.22, 8.70, 6.98	543.2625
D	9.00, 9.84, 9.39, 8.44, 9.45, 9.09, 8.22	576.7303
E	9.50, 9.55, 10.00, 10.30, 8.98, 7.98, 9.13	615.2210
F	9.69, 9.64, 7.61, 8.41, 7.95, 8.69, 7.86	515.9641
G	8.03, 8.86, 8.75, 10.03, 7.06, 7.69, 8.03	499.0936
Sum of all values: = 425.22		3733.2893
		— 3690.0099
		43.2794 = Total sum of squares

$$\text{Correction: } = \frac{(425.22)^2}{49} = 3690.0099$$

The sum of squares between the treatments is found thus:

Treatment	Sum of values	Squares of the sums of the values	
A	56.96	3244.4416	
B	59.90	3588.0100	
C	61.19	3744.2161	
D	63.43	4023.3649	
E	65.44	4282.3936	
F	59.85	3582.0225	
G	58.45	3416.4025	
Sum	425.22	25,880.8512 / 7	= 3697.2645
			−3690.0099
			7.2546

$$\text{Correction: } \frac{(425.22)^2}{49} = 3690.0099$$

Sum of squares between the treatments = ------- 7.2546

Analysis of Variance		Degrees of Freedom
Total sum of squares	43.2794	48
Sum of squares between the treatments	7.2546	6
Sum of squares due to error	36.0248	42

The total sum of squares is subject to 48 degrees of freedom, there being 49 observations and the only fixed value is the general mean, 8.68; and the sum of squares between the treatments is subject to 6 degrees of freedom, for there are 7 treatments. Thus there remain 42 degrees of freedom for the sum of squares due to error and therefore, for the variance due to error, that is, within the treatments.

The variance of a single value due to error would be equal to $36.0248/42 = 0.8577$, that is, the same as previously found; and the standard deviation of a single value is equal to $\sqrt{0.8577} = 0.93$. The standard deviation of a mean of 7 values is equal to $\sqrt{0.8577/7} = \sqrt{0.1225} = 0.35$, and the standard deviation of the difference between any two means of 7 values each would be $\sqrt{2(0.1225} = \sqrt{0.2450} = 0.50$. In order that the difference in yields between any two means were significant they would have to exceed $1.74 \times 0.50 = 0.87$, for 1.74 is the value of "t" that corresponds to once in 22 cases that this value be exceeded by chance with 30 degrees of freedom, since 30 is the value most near to 42 in the list. If the means on page 9 are looked over, it will be seen that by using this same reasoning treatment E is superior to treatments G and A for $9.35 - 8.35 = 1.00$, which exceeds the value 0.87, and $9.35 - 8.14 = 1.21$, which also exceeds the value 0.87.

Hayes' Deviation From the Mean Method

In the application of this method one follows the same procedure that was followed under Fisher's Unrestricted Analysis of the Variance Method until the standard deviation of the mean of any treatment is found, which was there found to be equal to 0.35. Finding then what per cent this standard deviation is of the general mean of all the treatments, 8.68, one finds:

$$0.35 \times 100\% / 8.68 = 4.03\%$$

Multiplying now this generalized standard deviation in percent by each mean the standard deviations corresponding to each mean are obtained; these appearing at their sides respectively in the list which follows:

Treatment	Mean	Standard deviation of the Mean	Variance of the Mean
E	9.35	0.38	0.1444
D	9.06	0.37	0.1369
C	8.74	0.35	0.1225
B	8.56	0.34	0.1156
F	8.55	0.34	0.1156
G	8.35	0.34	0.1156
A	8.14	0.33	0.1089

Applying the same reasoning that was used on page 207, one deducts that all the treatments whose means be higher than $9.35 - 1.74 \times 0.38 = 9.35 - 0.66 = 8.69$, will not be statistically different from treatment E. One can say then, that treatment E does not differ statistically from treatments D and C.

The standard deviation of the differences between the mean E and the means of the other treatments are found as follows:

Between E and B:

$$D_d = \sqrt{0.1444 + 0.1156} = \sqrt{0.2600} = 0.51$$

The amount to be exceeded by the difference is $1.74 \times 0.51 = 0.89$. As $9.35 - 8.56 = 0.79$ it is evident that treatment E does not differ significantly from treatment B.

In the same way the differences between the mean of E and those of F, G and A are tested concluding that treatment E is superior only to treatments G and A.

Method of Randomized Blocks

To apply this method, as has been said before, the field must be divided into sections of various plots each, and the repetition of each treatment within any one of these sections or blocks must be placed by chance.

The procedure to be followed in order to calculate the standard deviation due to error can then be modified by reducing the sum of squares due to error by that quantity which corresponds to the variation between blocks, and which therefore corresponds to differences in fertility between the different sections or blocks into which the experimental field has been divided. The variation due to error remains in this way reduced if the variation between blocks is larger than the variation due to experimental error.

To illustrate the method use is made of diagram No. 1, assuming that the blocks are constituted by all the plots in horizontal rows, that is, block No. 1 consists of the plots where the treatments are found in the order that follows: B, D, A, G, F, E, and C.

The total sum of squares is the same as in the Unrestricted Method: 43.2794. To this quantity one has to subtract now the sums of squares due to the variation between the treatments and to variation between the blocks in order to obtain the sum of squares due to error.

The sum of squares corresponding to the variation between the treatments is equal to that in the unrestricted method, 7.2546, and therefore the sum of squares due to the variation between blocks and that due to error is now 36.0248.

To find the sum of squares due to the variation between blocks, one proceeds as was done to find the sum of squares due to the variation between the treatments, thus:

Block	Sum of values	Squares of the sums of the values	
1	59.97	3596.4009	
2	63.44	4024.6336	
3	63.88	4080.6544	
4	62.71	3932.5441	
5	60.72	3686.9184	
6	58.75	3451.5625	
7	55.75	3108.0625	
Sum	425.22	25880.7764 / 7	= 3697.2538 −3690.0099
			7.2439

$$\text{Correction} = \frac{(425.22)^2}{49} = 3690.0099$$

Sum of squares due to blocks = 7.2439.

The sum of squares due to error is reduced now to 36.0248 − 7.2439 = 28.7809. This sum of squares, however, is subject to 36 degreees of freedom, for the variation between the blocks is subject to 6 degrees of freedom, there being 7 blocks.

The variance of a single value due to error is now 28.7809/36 = 0.7995 and the difference between any two means must exceed now the quantity $1.74 \times \sqrt{2(0.7995)/7} = 1.74 \times \sqrt{1.5990/7} = 1.74 \times \sqrt{0.2284} = 1.74 \times 0.48 = 0.84$.

By this method, then, treatment E results superior to treatments A and G.

Latin Square Method

If the true distribution is now used, and the Analysis of the Variance Method is applied to it, one will obtain a more clear idea of the method in general. The latin square is the distribution for which it might be said that the method was developed, although there are experiments where various blocks are used each of which is by itself a latin square, and if the experiment were repeated for a number of years, that part of the sum of squares due to differences in climatic effects would have to be subtracted also.

To complete the analysis of variance according to the original distribution, one has only to subtract to the sum of squares assumed to correspond to error in the preceding method, the sum of squares corresponding to the variation between the columns, if the sum of squares corresponding to the blocks is assumed to correspond now to the files.

As previously, the sum of squares due to the columns is found as follows:

Column	Sum of values	Squares of the sums of the values	
1	61.94	3836.5636	
2	62.77	3940.0729	
3	58.38	3408.2244	
4	61.88	3829.1344	
5	64.88	4209.4144	
6	58.58	3431.6164	
7	56.81	3227.3761	
Sum	425.22	25882.4022 / 7	= 3697.4860
			−3690.0099
			7.4761

Correction: $\frac{(425.22)^2}{49} = 3690.0099$

The sum of squares due to error is reduced to 28.7809 — 7.4761 = 21.3048, with 30 degrees of freedom. The variance due to error is then 21.3048/30 = 0.7102. The standard deviation of the difference between any 2 means is now $\sqrt{2(0.7102)/7} = \sqrt{1.4204/7} = \sqrt{0.2029} = 0.45$. The difference between the means must exceed now the quantity $1.74 \times 0.45 = 0.78$.

Treatment E is thus proved superior to treatments B, F, G and A.

The following table resumes the Analysis of the Variance in this Experiment:

Variance due to:	Degrees of Freedom	Sum of squares	Variance
Columns	6	7.4761	1.2460
Files	6	7.2439	1.2073
Treatments	6	7.2546	1.2091
Error	30	21.3048	0.7102
Total	48	43.2794	

With this ends the illustration of the methods which determine if the difference between the means of the yields of 2 treatments is statistically significant or not, and we will now proceed to illustrate the method which determines if the mean of the differences between the correlated results of two populations is statistically significant or not.

"Student's" Method of Paired Results

Although this method is generally known as the "Student's" Method, Goulden says with a good deal of justice in "Statistical Methods in Agronomic Research" that to call this method in such a way tends to obscure "Student's" real contribution to statistical knowledge.

The best explanation that can be given here of this method is to illustrate it by applying it to the experiment under study. The paired results have to be the corresponding observations of the two series to be compared. For example, as each value of any treatment is found on the same file and in the same column with other two values of any other treatment, it is evident that 14 pairings may be done with the values of any two treatments, just as it was done on finding the coefficients of correlation in a previous method.

Following may be found the illustration of the pertinent comparations to do the interpretation of the results of the experiment by this method:

Between E and A:

Values of E	Values of A	Differences	Squares of the differences
9.50	7.45	2.05	4.2025
9.55	8.91	0.64	0.4096
10.00	9.73	0.27	0.0729
10.30	7.58	2.72	7.3984
8.98	8.36	0.62	0.3844
7.98	7.63	0.35	0.1225
9.13	7.30	1.83	3.3489
7.98	7.30	0.68	0.4624
10.30	9.73	0.57	0.3249
10.00	7.45	2.55	6.5025
9.55	8.36	1.19	1.4161
9.13	8.91	0.22	0.0484
9.50	7.58	1.92	3.6864
8.98	7.63	1.35	1.8225
		Sum = 16.96	30.2024
			−20.5458
			9.6566

Correction = $(16.96)^2/14 = 20.5458$
Mean = $16.96 / 14 = 1.21$
Sum of squares/n = $9.6566/14 = 0.6898$.
$Z = 1.21/\sqrt{0.6898} = 1.21/0.83 = 1.45$.

For $n = 14$, this value of "*z*" falls above 0.50 which is that corresponding to a probability in favor of their being different equal to 21/22 and therefore, the two treatments are statistically different. (In the *z* table, *n* is equal to the number of pairs of values compared.)

Since "t" $= z\sqrt{n-1}$ where "n" is the total number of paired observations and therefore "n − 1" is the number of degrees of freedom, it is obvious that the list of "t" may be used to determine the probabilities in connection with this method also.

Using the table or list of "t" to do the interpretation of the results by the use of this method we have:

Variance of a single difference: $9.6566/13 = 0.7428$.

Variance of the mean of the differences $= 0.7428/14 = 0.0531$.

Standard deviation of the mean of the differences $= \sqrt{0.0531} = 0.23$.

As there are 14 differences, there are 13 degrees of freedom. The quantity to be exceeded by the mean of the differences is equal to $1.82 \times 0.23 = 0.42$. As the mean of the differences is 1.21, it is therefore significant and the two treatments differ statistically.

In this same way we find the values of "z" for the differences between the treatments E on the one side and treatments D, B, C, F, and G on the other, obtaining the following values for "z":

Between E and D : 0.33
Between E and B : 0.77
Between E and C : 0.55
Between E and F : 0.67
Between E and G : 0.91

As the value of "z" to be exceeded is equal to 0.50 it is evident that treatment E is superior to all the other treatments except treatment D.

TABLE OF "z" AND "t"

"n"	"z"	"t"
1		6.95
2	6.95	3.09
3	2.18	2.46
4	1.42	2.22
5	1.11	2.08
6	0.93	2.01
7	0.83	1.96
8	0.74	1.92
9	0.68	1.89
10	0.63	1.87
11	0.59	1.85
12	0.56	1.83
13	0.53	1.82
14	0.50	1.81
15	0.48	1.80
16	0.46	1.79
17	0.45	1.79
18	0.43	1.78
19	0.42	1.78
20	0.41	1.77
21	0.40	1.77
22	0.39	1.76
23	0.38	1.76
24	0.37	1.76
25	0.36	1.75
26	0.35	1.75
27	0.34	1.75
28	0.34	1.75
29	0.33	1.74
30	0.32	1.74
Infinity	0.30	1.69

The values of "z" and "t" in the above table are those which correspond to a probability of 21/22 in favor of said difference being statistically significant. The "n" in the table of "z" means "the number of pairs of values compared" and the "n" in the table of "t" means "degrees of freedom" to which the difference is subject.

NORMAL CURVE PROBABILITIES

Per cent	X	Per cent	X	Per cent	X	Per cent	X
1%	2.58	15%	1.44	50%	0.6745	80%	0.25
2%	2.33	20%	1.28	55%	0.60	85%	0.19
3%	2.17	25%	1.15	60%	0.52	90%	0.13
4%	2.05	30%	1.04	65%	0.45	95%	0.06
5%	1.96	35%	0.93	70%	0.39	96%	0.05
10%	1.64	40%	0.84	75%	0.32	97%	0.04
						98%	0.03
						99%	0.01

The percentage represents the probability which the deviation from the mean of a value taken at random from the whole population has of exceeding the standard deviation of the population by "X" times.

Description of Contents

This paper comprises a brief and simple explanation of the fundamental principles underlying the use of the statistical methods most commonly used in agricultural research. Among the methods compared are Bessel's method, the deviation from the mean method, Fisher's method for the Analysis of Variance (including the following phases: Unrestricted method, method of Randomized Blocks, method of Latin Square), and "Student's" method for Paired Observations. An example for the application of each method and new tables devised to test exclusively whether a difference is statistically significant or not are also presented.

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A REVISION OF THE WEST INDIAN RACES OF *LOXIGILLA NOCTIS* (LINNAEUS)

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Some confusion has existed for many years concerning the various races of Bullfinches (*Loxigilla noctis*) occurring in the West Indies. Therefore during recent collecting trips to the Lesser Antilles I have endeavoured to accumulate series from as many points as possible. In addition I have examined, measured, and made notes upon the entire series of these birds in the U. S. National Museum, the Field Museum of Natural History, the Museum of Comparative Zoölogy, the American Museum of Natural History, and the Academy of Natural Sciences of Philadelphia. Thanks to the courtesies of the authorities of these museums it has been possible to examine a total of 396 specimens, including examples from all the islands on which the species is known to exist, and the types of most of the forms which have been recognized. The measurements of all these specimens were personally taken, so all may be regarded as comparable.

Loxigilla is a typically West Indian genus, being represented by two species and a number of races in the Bahamas and Greater Antilles, and in the Lesser Antilles by the extinct *L. grandis* of St. Kitts, and by the various races of *L. noctis* and the closely allied *L. barbadensis*. The only form of *Loxigilla* known from outside the West Indies is *Loxigilla noctis propinqua* from Guiana, a form of which it has not been my privilege to examine specimens, and which is accordingly not included in this revision.

From the West Indies I have recognized nine races of *Loxigilla noctis*, in addition to the closely related species, *Loxigilla barbadensis*. Of these nine races one, *Loxigilla noctis desiradensis*, is described as new, another which has not generally been recognized, *L.n. chazaliei*, is considered as valid and the distribution of two others, *L.n. ridgwayi* and *L.n. coryi*, has been found to vary considerably from that which has been generally assigned to them.

All measurements in this paper are expressed in millimeters.

Loxigilla noctis coryi (Ridgway)

Pyrrhulagra coryi RIDGWAY, Auk, 15, Oct. 1898, p. 323 (St. Eustatius, type in U.S. National Museum, No. 80965).

Subspecific characters: Adult male.—Entire plumage black, except a small superciliary stripe, chin, throat and under tail-coverts, which are chestnut-rufous, and the under wing-coverts, which are largely white; the bill, legs and feet are black, the soles of the feet being tinged with light grayish; iris dark brown. *Adult female.*—Upper surface dull grayish olive brown, the wings and tail fuscous, the primaries being slightly edged with grayish olive, and the greater wing-coverts broadly edged with cinnamon rufous; underparts deep olive gray, frequently more or less suffused with brownish; under tail-coverts light cinnamon; bill with the upper mandible dusky, the lower dark horn color; legs and feet slate gray, claws dusky, soles of feet tinged with yellow, iris dark brown. *Immature male.*—Similar in color to the adult female, but larger.

Measurements: Adult male.—5 specimens from Anguilla, wing 64.9–66.8 (65.82); tail 48.9–50.1 (49.80); culmen from base 14.7–15.8 (15.24); tarsus 18.9–19.5 (19.28). 1 specimen from St. Martin, wing 65.6; tail 54.5; culmen from base 15.0; tarsus 13.0. 1 specimen from Saba, wing 66.0; tail 48.0; tarsus 19.6; culmen from base 14.9. 8 specimens from St. Eustatius, wing 63.5–67.6 (65.35); tail 50.0–56.5 (53.10); culmen from base 15.3–17.0 (15.87); tarsus 18.8–19.8 (19.36). 24 specimens from St. Kitts, wing 65.0–69.4 (66.70); tail 48.8–54.3 (51.19); culmen from base 14.4–16.9 (15.76); tarsus 17.0–21.5 (19.54). 3 specimens from Nevis, wing 68.0–70.6 (69.20); tail 51.3–56.6 (54.57); culmen from base, 15.2–16.2 (15.80); tarsus 17.4–21.5 (18.83). *Female.* 2 specimens from Anguilla, wing 62.0–64.1 (63.05); tail 47.5–47.6 (47.55); culmen from base 14.0–14.5 (14.25); tarsus 18.0–18.5 (18.25). 1 specimen from Saba, wing 63.7; tail 47.6; tarsus 19.6; culmen from base 14.8. 5 specimens from St. Eustatius, wing 62.0–65.8 (63.72); tail 46.3–49.0 (47.82); culmen from base 14.6–15.4 (14.92); tarsus 18.7–19.7 (19.30). 6 specimens from St. Kitts, wing 63.9–65.5 (64.43); tail 48.4–52.3 (49.38); culmen from base 15.0–16.0 (15.57); tarsus 18.9–20.0 (19.25). *Immature male.* 2 specimens from Anguilla, wing 63.5–64.2 (63.85); tail 46.2–49.2 (47.70); culmen from base 14.7–15.2 (14.95); tarsus 18.8–19.0 (18.90). 5 specimens from St. Eustatius, wing (average of 4) 64.0–67.3 (66.32); tail 47.3–49.8 (48.42); culmen from base 15.4–16.2 (15.82); tarsus 19.1–20.6 (19.94). 6 specimens from St. Kitts, wing 63.9–65.5 (64.43); tail 48.4–52.3 (49.38); culmen from base 15.0–16.0 (15.57); tarsus 18.9–20.0 (19.25). *Immature Female.* 1 specimen from St. Kitts, wing 61.8; tail 43.8; culmen from base 15.2; tarsus 18.0.

RANGE: Anguilla, St. Martin, Saba, St. Eustatius, St. Kitts, Nevis.

SPECIMENS EXAMINED: Anguilla 9; St. Martin 1; Saba 2; St. Eustatius 18; St. Kitts 45; Nevis 3.

REMARKS: Two adult males from Anguilla may be matched perfectly in color by St. Kitts birds. The other three are much lighter, but do not appear to be fully adult. I have a specimen

from St. Kitts in similar light plumage with a few dark feathers beginning to appear, indicating that the males when assuming the adult plumage attain red feathers on the throat before losing the body feathers of the immature plumage. Fully adult males from all these islands are much darker in color than those from Barbuda and Antigua. The single specimen from St. Martin agrees well in color with the series from St. Eustatius, and there is no doubt that the birds from these northern islands should be regarded as *coryi* instead of as *ridgwayi*, under which name they have hitherto been listed.

Birds from Nevis agree well with those from St. Kitts in color, but they average considerably larger and may represent a new subspecies, but unless further material corroborates this difference it seems best to regard the Nevis birds as *coryi*.

Apparently this bird sometimes breeds before attaining fully adult plumage, as a male just beginning to show red on the throat collected at Friar's Bay, St. Kitts on June 25, 1935 had its testes so enlarged as to indicate breeding.

Loxigilla noctis chazaliei Oustalet

Loxigilla Chazaliei Oustalet, Bulletin de la Société Zoologique de France, 20, 1895, p. 184. (Barbuda, collected by Count Dalmas, type probably in the Paris Museum.)

Subspecific characters: Similar in coloration to *L. n. coryi*, but the adult males are much lighter in color and smaller in size. They resemble *L. n. ridgwayi* most closely, but are smaller and lighter than that form. The under tail-coverts are chestnut-rufous. The immature males are of a lighter, more yellowish brown color above than those of any other form.

Measurements: Adult male. 5 specimens from Barbuda, wing 64.0–66.3 (64.84); tail (average of 4) 50.00–50.7 (50.30); culmen from base 14.5–15.5 (15.16); tarsus 17.3–21.0 (18.68). *Female.* 3 specimens from Barbuda, wing 61.8–68.9 (65.32); tail 45.0–53.5 (49.63); culmen from base 14.5–16.5 (15.53); tarsus 17.9–20.0 (18.96). *Immature male.* 3 specimens from Barbuda, wing 58.7–62.5 (60.73); tail 49.4–50.0 (49.67); culmen from base 15.0–15.7 (15.33); tarsus 16.5–19.4 (18.10).

Range: Restricted to the Island of Barbuda.

Specimens examined: Barbuda, 11.

Remarks: This is the lighest colored and the smallest of all the West Indian races of *L. noctis*. *L.n. ridgwayi* of Antigua is the form which most closely approaches it, but that is slightly larger and noticeably darker. The difference in color is even more noticeable in the field than in the museum, but even there the darkest Barbuda

bird was found to be lighter than the lightest Antigua bird, clearly demonstrating this to be a distinct and valid race.

Loxigilla noctis ridgway (Cory), Cat. W. Ind. Birds, 1892, p. 15, 112, 150, part. (Antigua, type in Field Museum, No. 9059, collected May 2, 1890 by C. S. Winch).

Subspecific characters: Similar to *L. n. coryi*, but decidedly lighter, the adult male being grayish black instead of pure black; the females and immature males are also paler. More similar to *L. n. chazaliei*, but larger and somewhat darker.

Measurements: Adult male. 14 specimens from Antigua, wing 61.6–67.8 (65.69); tail 48.5–53.2 (51.56); culmen from base 14.8:16.1 (15.31); tarsus 17.3–20.0 (18.27). *Female.* 2 specimens from Antigua, wing 59.6–66.3 (62.95); tail 50.5–51.4 (50.95); culmen from base 15.0–15.3 (15.15); tarsus 17.5–19.2 (18.35). *Immature male.* 2 specimens from Antigua, wing 63.5–63.7 (63.60); tail 51.0–51.6 (51.30); culmen from base 15.2–16.1 (15.65); tarsus 18.3–18.5 (18.40).

Range: Restricted to the Island of Antigua.

Specimens examined: Antigua, 18.

Remarks: Decidedly the lightest of all the West Indian races of *L. noctis* except *L. n. chazaliei*, than which it is somewhat darker and slightly larger.

Loxigilla noctis dominicana (Ridgway)

Pyrrhulagra dominicana, Ridgway, Auk, 15, Oct. 1898, p. 323 (Dominica, type in U. S. National Museum, No. 77829, collected by F. A. Ober at Mt. Lake, 2,500 feet altitude).

Subspecific characters: Similar to *L. n. coryi*, but much larger, and averaging darker, the adult males being consistently of a deep black color, with the under tail-coverts rufous or largely rufous. The females are also darker and more tinged with rufous above.

Measurements: Adult male. 18 specimens from Guadeloupe and Grande Terre, wing 67.2–74.3 (71.01); tail 49.0–57.2 (52.94); culmen from base 15.0–16.7 (15.61); tarsus 19.0–20.9 (20.16). 2 specimens from Marie Galante, wing 71.9–72.3 (72.10); tail 55.0–56.7 (55.85); culmen from base 14.8–15.3 (15.05); tarsus 17.6–20.0 (18.80). 12 specimens from Dominica, wing 71.4–75.3 (73.64); tail 52.7–60.0 (54.85); culmen from base 15.0–17.1 (15.77); tarsus 18.0–20.9 (20.03). *Female.* 1 specimen from Montserrat, wing 66.0; tail 47.3; culmen from base 15.7; tarsus 20.5. 24 specimens from Guadeloupe and Grande Terre, wing (average of 23) 64.0–70.1 (66.61); tail 46.3–52.3 (49.43); culmen from base (average of 20) 14.5–16.3 (15.26); tarsus (average of 22) 17.6–20.7 (19.25). 1 specimen from Marie Galante, wing 65.3; tail 48.4; culmen from base 15.0; tarsus 19.4. 10 specimens from Dominica, wing (average of 8) 64.8–70.3 (67.74); tail (average of 9), 45.3–51.0 (48.33); culmen from base (average of 9) 14.4–20.5 (16.28); tarsus 18.7–21.0 (19.98). *Immature male.* 3 specimens from Guadeloupe and Grande Terre, wing 66.7–67.9 (67.23); tail 47.2–49.0 (48.23); culmen from base 14.8–15.8 (15.20); tarsus 18.9–19.1 (19.00). 2 specimens from Dominica, wing 68.9–69.0 (68.95); tail 46.0–48.7 (47.35); culmen from base 15.7–16.8 (16.25); tarsus 19.9–20.8 (20.35).

Range: Guadeloupe and Grande Terre, Marie Galante, Dominica and probably Montserrat.

Specimens examined: Guadeloupe and Grande Terre 45; Marie Galante 3; Dominica 24; Montserrat 1.

Remarks: This is a very large and dark form, the largest of all the races of *L. noctis*. Specimens from Dominica average somewhat larger than those from the other islands particularly in the wing measurements, but these differences seem too slight to warrant subspecific recognition. No constant differences in color can be noted. As I have seen but one specimen (a female) from Montserrat, I am including that island doubtfully in the range of this race, although the specimen in question agrees fairly well with examples from Guadeloupe, and is probably referable to this form.

Loxigilla noctis desiradensis subsp. nov.

Type: Coll. Field Museum No. 23676, adult male, Desirade, March 7, 1886, collected by W. B. Richardson.

Subspecific characters: **Similar to *L. n. dominicana* in color, but with shorter wing and tarsus.**

Measurements: ***Adult male.*** **4 specimens from Desirade, wing 67.3–69.6 (68.35); tail 48.1–59.4 (54.60); culmen from base 15.5–15.9 (15.62); tarsus 17.4–20.0 (18.15). The type measures wing 68.0; tail 59.4; culmen from base 15.5; tarsus 17.4.** ***Adult female.*** **2 specimens from Desirade, wing 62.0–65.5 (63.75); tail 47.0–49.2 (48.10); culmen from base 14.8–15.7 (15.25); tarsus 17.9–18.4 (18.15).**

Range: Island of Desirade, near Guadeloupe.

Specimens examined: Desirade 6.

Remarks: This form is most closely related to *L.n. Dominicana*, but the wing and tarsus average decidedly shorter. In *dominicana* these average 72.06 and 20.02 respectively for adult males and 66.82 and 19.36 for females. Thus the wing of *desiradensis* averages 3.71 millimeters shorter in males and 3.07 millimeters shorter in females, while the tarsus averages 1.87 millimeters shorter in males and 1.21 in females.

Loxigilla noctis noctis (Linnaeus)

[*Fringilla*] *noctis* Linnaeus, Syst. Nat., ed. 12, 1, 1766, p. 320 ("Jamaica", "Mexico", Martinique).

Subspecific characters: **Similar in coloration to *L. n. dominicana*, but the adult males with the under tail-coverts chiefly black, sometimes with a little admixture of rufous or chestnut, and averaging very slightly smaller, while the females are lighter and less tinged with rufous above.**

Measurements: Adult male. 20 specimens from Martinique, wing 67.0–73.0 (71.33); tail 49.7–54.1 (52.84); culmen from base 14.6–16.0 (15.33); tarsus 18.1–21.0 (19.65). *Female.* 5 specimens from Martinique, wing 65.6–68.8 (67.00); tail (average of 4) 48.6–52.0 (50.40); culmen from base 14.5–16.5 (15.40); tarsus (average of 2) 17.3–19.1 (18.20). *Immature male.* 1 specimen from Martinique, wing 67.9; tail 51.3; culmen from base 16.6; tarsus 19.3.

Range: Island of Martinique.

Specimens examined: Martinique 26.

Remarks: The adult males are quite similar to *L.n. dominicana*, differing chiefly in the small amount of rufous in the under tail-coverts. The females are lighter and less tinged with rufous above than those of *dominicana*, but darker and less olive than those of *L.n. sclateri*, being intermediate between the two, but very distinct from either.

Loxigilla noctis sclateri Allen

Loxigilla noctis sclateri. Allen, Bull. Nutt. Orn. Club, v, July 1880, p. 166 (St. Lucia, type in Museum of Comp. Zoöl., collected by John Semper, no date on label).

Subspecific characters: Adult males are similar in coloration to those of *L. n. noctis;* females and immature males are much lighter in color, being light olive above, and also lighter below; both sexes are smaller.

Measurements: Adult male. 45 specimens from St. Lucia, wing 65.8–71.6 (68.85); tail 46.3–55.0 (50.56); culmen from base 13.7–15.9 (14.74); tarsus (average of 4), 18.0–19.9 (18.92). *Female.* 15 specimens from St. Lucia, wing (average of 14) 62.8–67.9 (64.84); tail (average of 14) 44.5–52.6 (47.36); culmen from base 14.0–15.0 (14.52); tarsus 17.0–20.7 (18.75). *Immature male.* 2 specimens from St. Lucia, wing 64.5–64.6 (64.55); tail 44.0–46.0 (45.00); tarsus 18.7–19.6 (19.15); culmen from base 14.5–15.0 (14.75).

Range: Island of St. Lucia.

Specimens examined: St. Lucia 78 (including 16 unsexed birds measurements of which are not included).

Remarks: This form differs from *L.n. noctis* chiefly in its smaller size and the lighter coloration of the females and immature males, which are lighter than those of any other race with the exception of *L.n. ridgwayi* and *L.n. chazaliei.*

Loxigilla noctis crissalis (Ridgway)

Pyrrhulagra crissalis Ridgway, Auk, XV, Oct. 1898, p. 323 Cumberland Valley, St. Vincent, type in U. S. National Museum, No. 74083, collected Oct. 22, 1877 by F. A. Ober).

Subspecific characters: Similar to *L. n. dominicensis*, but slightly smaller, and the adult males are even deeper black; the chesnut-rufous area on the throat is more extensive, extending to the anterior portion of the chest; under tail-coverts rufous; females and immature males similar to those of *L. n. noctis*, but somewhat lighter, especially below.

Measurements: Adult male. 16 specimens from St. Vincent, wing 67.9–72.5 (70.05); tail (average of 15) 48.7:54.0 (50.57); culmen from base 14.4–16.5 (15.64); tarsus 17.8–20.5 (18.94). *Female.* 7 specimens from St. Vincent, wing (average of 5) 67.0–69.0 (67.98); tail (average of 5) 46.6–51.5 (49.00); culmen from base 14.4–15.6 (15.13); tarsus 18.0–20.4 (18.77). *Immature male.* 6 specimens from St. Vincent, wing 65.6–69.0 (67.11); tail 46.0–48.7 (47.40); culmen from base 15.6–16.1 (15.91); tarsus 18.3–19.9 (19.31).

Range: Island of St. Vincent.

Specimens examined: St. Vincent 29.

Remarks: This form, although very distinct, is most closely allied to *L.n. grenadensis* of Grenada, and may be distinguished by the characters mentioned under that species.

Loxigilla noctis grenadensis (Cory)

Pyrrhulagra noctis grenadensis Cory. Cat. W. Ind. Birds, 1892, p. 16, 112, 150, part (Grenada, type in Field Museum, No. 9041, without data, collected by J. G. Wells).

Subspecific characters: Similar to *L. n. crissalis*, but smaller; the adult males with the throat patch much more restricted and of a darker rufous color (with less of an orange tinge); under tail-coverts rufous, sometimes with admixture of black; the females are less olivaceous (more washed with brownish) above. The adult male has the iris dark brown; upper mandible dusky, the lower dark horn color; legs and feet slate gray, claws dusky, soles, tinged with yellow.

Measurements: Adult male. 38 specimens from Grenada, wing (average of 37) 65.3–70.1 (67.91); tail 45.5–53.0 (49.00); culmen from base (average of 36) 14.5:16.0 (15.23); tarsus (average of 37) 18.0–20.6 (19.25). *Female.* 12 specimens from Grenada, wing 62.5–66.8 (64.25); tail (average of 11) 44.0–49.3 (46.72); culmen from base 13.6–15.4 (14.39); tarsus 17.5–20.6 (18.62).

Range: Island of Grenada.

Specimens examined: Grenada 53 (including 3 unsexed specimens not measured).

Remarks:- This race resembles *L.n. sclateri* of St. Lucia in size and color more closely than *L.n. crissalis* of St. Vincent, with which form it has been proposed to unite it. The characteristics separating the latter two forms have been given under the subspecific characters. It may be noted that the type of *grenadensis* is an exceptionally dark

bird, darker than any other specimens examined from Grenada. It may not be out of place to mention here that, although this bird was formerly one of the most abundant birds in Grenada, it has now become decidedly scarce.

Loxigilla barbadensis Cory

Loxigilla barbadensis CORY, Auk, 3, July 1886, p. 382 (Barbados, type in Field Museum, No. 9047, collected February 4, 1886 by W. B. Richardson).

Specific characters: Similar in all stages to the female and immature stages of the lighter colored forms of *L. noctis*, being intermediate in color between *L. n. sclateri* and *L. n. ridgwayi*, but lacking the buffy or rusty tinge on the sides of the head and other parts, which is present in all forms of *L. noctis*.

Measurements: Adult male. 13 specimens from Barbados, wing (average of 11) 67.7–71.0 (69.29); tail (average of 11) 48.0–51.4 (49.93); culmen from base 14.9–16.5 (15.81); tarsus 18.1–21.5 (19.65). *Female.* 10 specimens from Barbados, wing (average of 8) 65.8–73.3 (69.74); tail (average of 8) 47.5–53.2 (50.15); culmen from base (average of 9) 14.9–15.8 (15.39); tarsus 18.1–20.5 (19.30). *Immature male.* 1 specimen from Barbados, wing 64.0; tail 45.0; culmen from base 14.4; tarsus 17.3.

Range: Island of Barbados.

Specimens examined: Barbados 24.

Remarks: This species is very closely allied to *L. noctis* and was in all probability derived from it. It differs from all forms of *L. noctis* in that the adult male never assumes the characteristic black and rufos plumage of that species, remaining in a plumage indistinguishable from that of the female. It greatly resembles the female and immature male of the lighter races of *L. noctis*.

STATUS OF THE PINK BOLLWORM IN PUERTO RICO DURING 1935–36

By L. C. Fife,
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Introduction

The production of Sea Island cotton in Puerto Rico, once an important industry, has been largely discontinued in recent years, partly because of the damage caused by the pink bollworm (*Pectinophora gossypiella* Saund.). In the year 1931 cotton plantings of the Sea Island variety covered an area of about 20,000 acres, Puerto Rico at that time being the world's largest producer. During the next three years no cotton was grown in Puerto Rico except 100 acres planted on the southern coast in September 1934 for seed. In 1935 approximately 2,000 acres and in 1936 about 3,000 acres were planted on the Island, the major part of these plantings occurring along the northern coast between Aguadilla and Arecibo.

In 1934 the Agricultural Division of the Puerto Rico Emergency Relief Administration started a project to assist in the rehabilitation of cotton-growing on the island. In view of the fact that the pink bollworm was one of the most important factors limiting the production of Sea Island cotton in Puerto Rico, this organization undertook a project to eradicate this pest. Wild cotton that grew abundantly in waste places and was the most important reservoir for the carry-over of the worms was almost eradicated by this organization in 1934–35. During that period 7,896,986 wild cotton plants were reported as having been destroyed.

Distribution

During 1935–36 the pink bollworm occurred throughout the commercial cotton-growing region along the northern coast, i. e., from Aguadilla to Arecibo. On the southern coast cultivated cotton was found infested only at Boquerón (La Costa) and at Sabana Grande, on the extreme southwestern part of the Island. Although small plantings of cotton were made also at Ponce, Juana Díaz, Villalba,

[1] In cooperation with the Puerto Rico Experiment Station of the United States Department of Agriculture.

Lajas, and Peñuelas they were not infested. A rather heavy infestation was found on wild cotton along the coast at Fajardo, Yabucoa, and Naguabo, on the extreme eastern part of the Island, and at Arroyo on the southeastern coast. Wild cotton was found infested also at Lajas and at Mayagüez. It appears that the pest's presence on the east and southeast coasts represents a separate infestation, probably from moths carried by air currents from adjacent islands on the east. The pink bollworm was not found on cotton in the interior of the Island. However, no commercial cotton plantings occur in the interior and very few wild cotton plants can be found in that part.

Infestation

Since the pink bollworm infestation in 1935 was rather low and occurred late in the season, the damage to cultivated cotton by this pest was negligible. At the time of the highest infestation of that year (December), the boll infestation per field averaged 30.2 percent and ranged from 3 to 95 percent. The principal reasons for this low infestation were as follows: (1) No cultivated cotton had been grown commercially in Puerto Rico during the previous 3 years; (2) wild cotton had been almost eradicated from the island in 1934–35; (3) no other favorable or preferred host plants occur in sufficient numbers to maintain a high population density of the pink bollworm in the absence of commercial cotton plantings over a period of 3 years.

In 1936 the pink bollworm infestation was unusually high throughout the commercial cotton-growing regions of the northern coast, except at Arecibo. As early as April of that year the boll infestation per field averaged 21.6 percent and ranged from no infestation at Arecibo to 63 percent at Isabela. A few fields in the latter locality, including an area of about 30 acres, were completely destroyed by June and the plants in several other fields were so badly damaged that they were pulled up before many bolls had opened. In August 27 fields were examined between Aguadilla and Arecibo. At that time the boll infestation per field averaged 24.3 percent and ranged from no infestation in two fields at Camuy to 100 percent in three fields at Isabela. Although no infestation counts were made in October, it was obvious that all fields were heavily infested at that time. Not less than 50 percent of the crop was destroyed in the district of Isabela and at least 30 percent over the entire cotton-growing area. The following were the principal reasons for this high infestation: (1) A very short dead season, if

any, was provided between the 1935 and 1936 crops, this permitting the pink bollworm to build up a dense population late in the season, thereby increasing the total number of long-cycle larvae to infest the 1936 crop; (2) fields were not thoroughly and immediately cleaned up after the harvest; (3) a high proportion (at least 65 percent) of the larvae in open cotton bolls were of the long-cycle type and the duration of this inactive stage for a maximum period of 172 days resulted in a very high carry-over; (4) although the seed capsules of Maga (*Montezuma speciosissima*) and Clamor (*Thespesia populnea*) were not heavily infested, these plants were factors in maintaining this pest during the dead season; (5) a considerable quantity of infested planting seed was used.

In 1935–36 the pink bollworm infestation on the southern coast was rather low. On cultivated cotton, infestation was found only at Boquerón and Sabana Grande. On eight fields examined in May, the boll infestation per field averaged 12.9 percent, and ranged from no infestation to 37 percent. In one field examined at Boquerón on June 4, however, the boll infestation was found to be 86 percent.

The geographic position of Puerto Rico is such that climatic conditions favor the development of the pink bollworm throughout the year. The long growing period is favorable to the increase of this species and is the most important factor affecting the abundance of this pest on cultivated cotton from year to year.

THE INTRODUCTION OF PARASITES OF THE SUGARCANE BORER INTO PUERTO RICO

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In July 1935, when the Bureau of Entomology and Plant Quarantine began by use of special funds, the study of certain insect pests of Puerto Rico the, writer was assigned to the Division of Foreign Parasite Introduction and delegated to exploratory work in the British West Indies and in South America. His primary objective was to secure the natural enemies of the sugarcane borer (*Diatraea saccharalis* Fab.) for the control of this pest in Puerto Rico. Incidental thereto, shipments of certain species were also made to the United States. The work was begun in Trinidad, B. W. I., on August 12, 1935, and terminated in Peru on May 22, 1936.

INVESTIGATION IN TRINIDAD

In addition to *Diatraea saccharalis*, there are two other species in the same genus that are important pests of sugarcane in Trinidad. As a matter of fact both of them, *D. impersonatella* Walk. and *D. canella* Hamps., have been much more serious there for several years than *saccharalis*. In all the writer's collections of borers for the rearing of parasites the numbers of *impersonatella* and *canella* far exceded those of *saccharalis*.

The actual collecting and rearing of borers was begun on August 26 and continued to the middle of October 1935. The collection of borers was confined to dead hearts of sugarcane. During these 7 weeks 17,630 dead-heart shoots of sugar cane were collected, and they produced, upon dissection, 639 pupae and 4,653 larvae of the three species. No parasites emerged from the pupae, but three species of larval parasites were reared. The commonest of them was the fly *Theresia claripalpis* Van der Wulp, parasitizing 9.2 percent of the borers; the fly *Stomatodexia diadema* Wied. was responsible for killing 1.1 percent, and the braconid *Apanteles diatraeae* Mues., about 0.05 percent. This braconid is said to be more common on *Diatraea* spp. attacking rice in Trinidad, killing 100 times as many as it attacks in cane. *Stomatodexia* is believed to be a

seasonal parasite, being more common in the summer than in the fall. The writer's work was apparently begun just too late to reveal the true effectiveness of this dexiid.

No parasites were forwarded from the rearings in Trinidad. While the work there was in progress three trips were made to other countries to arrange for the conduct of projects, and, what is more important, although nearly 500 puparia and cocoons of the three species of parasites were obtained, at no time was the emergence of adults sufficiently large to justify air-express shipments.

In connection with the rearing of the dipterous parasites it might be mentioned that neither *Theresia* nor *Stomatodexia* adults would mate when placed in cages covered with white, coarse mosquito netting, but when the cages were painted green mating was induced. The cages were cylindrical, 14 inches in diameter and about 22 inches in height. As a precaution against molestation by ants, they were suspended from the ceiling of the laboratory, and were doubly protected from them by the use of sticky tree-banding material.

Investigations in British Guiana

The work in British Guiana had two distinct phases, the breeding of the Amazon fly (*Metagonistylum minense* Towns.) and the rearing of the parasites of the sugarcane borer indigenous to British Guiana.

In 1932, while in search of beneficial insects for the control of the large moth borer *Castnia licoides* Boisd. in the jungles of the Amazon basin in Brazil, J. G. Myers, of the Imperial Bureau of Entomology, discovered a new parasite attacking the larvae of *Diatraea saccharalis* infesting the two grasses *Paspalum repens* and *Echinochloa polystachya* about 500 miles from the Atlantic Ocean. His attempt to bring this unknown parasite with him into British Guiana that year failed on account of transportation difficulties. This obstacle was overcome the following year when the British Guiana Sugar Producers' Association, anxious to cooperate with the British Guiana Department of Agriculture, volunteered to purchase a launch and hire an experienced navigator to operate it. Thus, in the summer of 1933, Dr. Myers succeeded in bringing 200 adults of *Metagonistylum* into the entomological laboratory at Georgetown, Demarara. It cost the combined treasuries of these two organizations approximately $35,000 to get those 200 individuals of the Amazon fly. Yet it was an investment of inestimable value! During the short time since its introduction and colonization in the cane fields

of the country it has saved the sugar growers many times that amount. The justification of their faith in this parasite is amply demonstrated to one who visits the sugarcane fields on the plantations where liberations were made. It may be seen in abundant numbers everywhere. In 1934 it was introduced into the Island of St. Lucia, where its establishment, dispersion, and control of the borer, as observed by the writer, may be said to be phenomenal. As soon as arrangements had been completed for securing material for importation into Puerto Rico and the United States, all efforts were concentrated on breeding and sending as many adults as possible to assure adequate numbers for establishment.

Particular acknowledgment is due to the Hon. J. Sidney Dash, Director of the Department of Agriculture of British Guiana, and to the British Guiana Sugar Producers' Association, for permission to collect material in colonized areas and for aid given during the course of the rearing work.

The breeding of the Amazon fly involved the careful mating of the female, the dissection of her ovaries at the end of the gestation period of 7 days to secure first-stage maggots, the inoculation of the *Diatraea* borers with these maggots, the care of the inoculated borers during the period of development of the fly maggot, and the removal and care of the resulting puparia and of the adults emerging from them.

The airplane schedule in effect during the period of the operations in British Guiana called for only weekly service to Puerto Rico. Beginning October 29, ten shipments were made at weekly intervals, representing a total of 6,575 adults of *Metagonistylum*, of which 88.6 percent reached their destination alive. In some of these consignments two other species of *saccharalis* parasites were included in small numbers. Out of 8 adults of *Stomatodexia diadema* and 62 adults of *Bassus stigmaterus* (Cress.), all except 1 *Bassus* were alive upon reaching Puerto Rico.

Literature records at least 12 species of parasites of *Diatraea saccharalis* larvae and pupae indigenous to British Guiana. Bulk rearings of sugarcane borers were undertaken in the expectation that at least some of these species would be found in sufficiently large numbers to permit an attempt at their establishment in Puerto Rico. Arrangements were made with four sugar plantations, located in different parts of the country, for the collection of *saccharalis* larvae and pupae, which were to be forwarded daily to the laboratory at Georgetown. The entire month of December 1935 was devoted to this work. More than 13,000 borers (of all stages) and pupae of

the sugarcane borer were reared in the laboratory; yet only two species of parasites were recovered. These were *Bassus stigmaterus* and the recently introduced Amazon fly, both parasites of the larvae. It was indeed surprising that not a single individual of the many other species recorded from this country was obtained from such a large and representative mass of material.

Investigations in Peru

In developing the project it was considered wise to introduce parasites from regions of diverse climatic conditions. The Amazon fly obtained in British Guiana has a decided preference for swampy or semiswampy conditions. This may be accounted for by the fact that its original home is along the banks of the Amazon River and it attacks its host inhabiting the grasses in the swamps bordering the river. One reason for the selection of Peru for the conduct of our search for the beneficial insects of the sugarcane borer was its climate, which was in marked contrast to that in British Guiana. Much of the sugarcane in Peru is grown in certain of the numerous valleys along its extensive west coast. Although very near the equator, the climate is subtropical, owing to the cooling effects of the Humboldt current from the Antarctic Ocean. For practically its entire length of 1,300 miles this coastal belt is almost rainless and is virtually destitute of vegetation except where irrigation makes cultivation possible. Most of these valleys are intensely cultivated and rendered fruitful by extensive systems of irrigation.

Three species of *Diatraea* are recorded from Peru, but only *saccharalis* is of economic importance. Two of the four parasites of *saccharalis* indigenous here, the dexiid fly *Theresia claripalpis* and the wasp *Ipobracon rimac* Wolc., were found in extraordinary abundance during the period of operation in Peru, April 7 to May 21, 1936. Both species were found in all the cane and numerous corn fields in the region about Trujillo. More than 12,000 puparia of the dexiid fly were accumulated in 3 weeks, and more than 13,000 adults of the wasp were collected in 29 days.

All the field-collected wasps and the adults emerging from the collection of puparia were cared for in a large storage cage of cheese-cloth, having a wooden frame 6½ by 6½ by 3 feet, until ready to be shipped. The upper frame and the uprights of the cage, towards the course of light, were literally covered with cubes of white sugar as food, and water was furnished by wetting the cheese-cloth on the sides of the cage and every 2 hours throughout the day. The

humid atmosphere produced in the cage by this wetting made the sugar more easily available to the adults.

The adult wasps and flies were shipped to their destinations in distinct types of cages. Metal cylindrical containers were used for *Theresia,* and wooden cages of the type used in the United States for shipping the parasites of the oriental fruit moth were utilized for *Ipobracon.* On the morning of the days of departure of the airplanes the parasites were prepared for shipment. Each insect was examined before being placed in the container, a practice which the writer has strictly followed in all shipments from foreign countries, and is specially necessary in the case of field-collected material. Since Peru had more frequent airplane service than British Guiana, it was possible to forward two consignments each week. A total of 13,533 adults of *Ipobracon rimac* were shipped from Peru, of which 10,705 went to Puerto Rico and the remainder, 2,828 adults, to the United States. The mortality en route to Florida was 21 percent, while to Puerto Rico, a trip requiring 2 days longer, it was 24.1 percent. In each case the mortality among the females was greater than among the males. Eighty-one percent of the adult wasps forwarded from Peru were females and only 19 percent males. Three hundred and fourteen adults of *Theresia claripalpis* were sent to Florida with a loss of 20.4 percent, while the mortality en route for the 1,713 flies shipped to Puerto Rico was 66.5 percent. For the four that reached Puerto Rico according to schedule the mortality was only 32.4 percent, but three of the consignments were misrouted or otherwise delayed, with consequent heavier mortalities.

Summary

Search for the parasites of the sugarcane borer (*Diatraea saccharalis* Fab.) was conducted in five countries in the American Tropics, in three of which actual field and laboratory work was performed. Three dipterous and two hymenopterous parasites were found and shipped to Puerto Rico and Florida, the former receiving 19,063 adults and the latter 3,142. The shipments to Puerto Rico comprised 8,296 flies and 10,767 wasps, while the shipments to Florida totaled 314 flies and 2,828 wasps.

THE IMPORTATION OF COCCINELLID ENEMIES OF DIASPINE SCALES INTO PUERTO RICO

S. M. DOHANIAN,
Bureau of Entomology and Plant Quarantine, United States Department of Agriculture.

One of the projects assigned to the writer in his recent investigations of beneficial insects in the American Tropics was the introduction of the predators of the coconut scale (*Aspidiotus destructor* Sign.) into Puerto Rico. This had been considered desirable in view of the presence of that pest in destructive numbers in Puerto Rico and the phenomenal success attained in its control in the Fiji Islands shortly after the introduction of coccinellids from Trinidad, B. W. I., in 1928. While this work was under way it was found possible to secure sufficient numbers of the different predators to provide shipments to Florida for use against the same pest and to California for testing upon the California red scale (*Chrysomphalus aurantii* Mask.).

The coconut palm is found throughout the Island of Puerto Rico, but extensive groves occur only along the seacoast, especially on the eastern and northeastern shores. Not only is *Aspidiotus* present wherever the coconut palm grows, but it attacks a dozen or more additional host plants. In Florida *A. destructor* is recorded from the southerly end of the peninsula and according to Merrill and Chaffin (**1**) it infests banana, mango, coconut, date, and Chinese fan.

COCCINELLID PREDATORS IN TRINIDAD

In Trinidad the coconut as an agricultural product is surpassed in importance only by cacao and sugarcane. In the southwestern corner and along practically the entire eastern shore of the island coconuts are grown almost to the exclusion of other crops. Numerous large plantations are scattered along the northern shore and in the northwestern corner of the island, as well as to the leeward of the northern range of mountains. Smaller groups of the palm may be found in other parts of the island. Nowhere are these trees free from the coconut scale. In the spring of 1936, however, although the infestation was general in distribution, the intensity was variable.

At least five species of coccinellid beetles have been recorded as predators on *Aspidiotus destructor* in Trinidad. Taylor (**2**) lists

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them as *Cryptognatha nodiceps* Marsh., *C. simillima* Sic., *Azya trinitatis* Marsh., *Scymnus aencipennis* Sic., and *Pentilia insidiosa* Muls. The present writer's investigations revealed three others, two being species of *Hyperaspis* and the third still undetermined. The species known in Trinidad as *Pentilia insidiosa* has been determined by coleopterists of the Bureau of Entomology and Plant Quarantine to be *Pentilia castanea* Muls., and by those of the California Citrus Experiment Station as *Azya trinitatis* Marsh. To avoid confusion the species will be referred to in this article as *Pentilia castanea.*

Two of the eight species represented in the writer's field collections overwhelmingly outnumbered all the others, nearly 90 percent of the insects shipped being *Cryptognatha nodiceps* and *Pentilia castanea* in about equal abundance. The former was common throughout the island and appeared in varying numbers in all the daily collections. In one region, however, it was exceeded in the numbers collected by *P. castanea.* In the groves along the eastern shore between Manzanilla and Biche and for 2 or 3 miles south of Biche, *Pentilia* was found in extraordinary abundance late in February and early in March, being fully three times as numerous as *nodiceps.* The other species encountered appeared to play an insignificant role in the control of *Aspidiotus,* and were never found in large numbers, at least not during the period of the writer's activities from January to March 1936. Yet, however small the representation of these minor species in the collections, they were always included in the shipments in the hope that under the conditions of their new envoronment they might become important factors in the control of this or some related pest. The two dominant species appeared to be much more scarce in the inland coconut groves than in those along the shore, despite the absence of any appreciable difference in the intensity of *Aspidiotus* infestation. Was this due to soil conditions, to their isolation from the large groves, or to other undetermined factors? It would have been interesting to study the reasons for this condition, but time did not permit.

Collection and Shipment

In the field the beetles were collected in 4-inch glass vials. The daily collections were placed in cylindrical glass jars, 8 inches in diameter and 12 inches high. Some of these jars contained coconuts, one to each jar, and others coconut fronds, heavily infested with *Aspidiotus.* This food was changed as necessary. Moisture was furnished daily by wetting the cheesecloth coverings of the jars.

When sufficient numbers had accumulated to warrant an air-express shipment, the beetles were packed and shipped.

In Trinidad, as in many other tropical countries visited, Caucasian peoples sleep in beds sheltered by mosquito netting. Such protective covering is sometimes cylindrical and narrow at the top but wide enough at the bottom to cover the bed on all its sides, and sometimes rectangular, conforming to the size and shape of the bed. Such protection in vogue at the Imperial College of Tropical Agriculture, where the writer made his headquarters, was of the latter type, and in his work in Trinidad it served a double purpose. At night it eliminated annoyance by mosquitoes and numerous other similar pests, and the days that the beetles were to be prepared for shipment it provided a convenient cage for the separation of the species. The jars containing the adults were placed under this netting and the beetles allowed to escape a few at a time. As they alighted on the sides of the netting towards the source of light from the windows, they were gathered in 4-inch vials, five adults to a vial. When 10 to 15 vials contained their quota of beetles, they were taken to the window, examined, and classified, the numbers of each species being recorded, and were then placed in the shipping containers. The operation was repeated until all the beetles were examined.

The shipping containers were of the usual mailing-tube type used by Bureau workers in the United States. Additional roosting surface was provided in each by the insertion of a tightly fitting triangular piece of chicken wire (¼-inch mesh) cut to size. Within its meshes were securely held two pieces of dental wick saturated, but not dripping, with a very dilute solution of sugar and water, to furnish water, humidity, and food. No host scales or any other food was furnished. The tubes were then wrapped in corrugated paper, and within its folds a slip of paper was placed bearing the numbers and species of the beetles therein, the dates and places of collection, the date of shipment, etc. In addition to the name and address of the consignee the following labels also were pasted on the outside of the package: "Permit of Entry of Beneficial Insects into the United States," "Rush," "Fragile," and "Handle with Care—Live Insects." Air express was used in all shipments.

Species Shipped and Their Numbers

Six consignments were forwarded from Trinidad, two of which went to Puerto Rico for liberation and breeding, two to Florida for direct liberation, and two to California for breeding in the laboratory

and subsequent release in the spring. Both consignments to Puerto Rico were reported to have arrived in excellent condition. The first of the two lots sent to Florida also reached its destination in excellent condition and with only 2 percent mortality. The second shipment, however, was not released for several days after arrival owing to inclement weather, with a consequent heavy mortality of 73 percent. The first lot of beetles sent to California was a total loss, having frozen to death en route owing to misrouting somewhere in the United States. The second shipment had suffered a mortality of 52 percent upon reaching Riverside, Calif.

The numbers of the various species sent to the several destination, with the dates on which the shipments left Trinidad, are given in Table 1. Among the 11 individuals of unknown species included in the second consignment to California two species of *Hyperaspis* were represented, according to determinations by P. H. Timberlake.

TABLE 1.—SPECIES AND NUMBERS OF COCCINELLID BEETLES SHIPPED FROM TRINIDAD TO PUERTO RICO AND THE UNITED STATES

Species	Number of beetles shipped to—									
	Puerto Rico			Florida			California			
	Jan. 19	Jan. 27	Total	Feb. 10	Mar. 10	Total	Feb. 16	Mar. 10	Total	Total
Cryptognatha nodiceps	147	126	273	156	149	305	174	111	285	863
Cryptognatha simillima	30	17	47	3	2	5	4	14	18	70
Pentilia castanea	38	30	68	25	595	620	46	141	187	875
Azya trinitatis	4	7	11	0	0	0	0	1	1	12
Scymnus aeneipennis	3	14	17	6	16	22	0	66	66	105
Unknown	6	9	15	9	0	9	18	11	29	53
Total shipped	228	203	431	199	762	961	242	344	586	1,978
Received alive	203	197	400	194	204	398	0	163	163	961
Percent alive	89.0	97.0	92.8	97.5	26.8	41.4	0	47.4	27.8	48.6

PRESENT STATUS OF THE IMPORTED PREDATORS

In a recent communication Harry S. Smith, of the Citrus Experiment Station, Riverside, Calif., stated:

"*Cryptognatha nodiceps* and *Azya trinitatis* reproduced on red scale (*Chrysomphalus aurantii*) infesting squash, but not in abundance. We did not succeed in propagating the other species. On June 17, 1936, 110 *Cryptognatha* and two *Azya* were colonized at Santa Barbara on red scale. In May a breeding stock of both species was supplied to the Orange County Insectary. A considerable increase in the stock was obtained there, and several hundred adults were liberated in scale-infested groves. However, we have not

yet observed propagation in the field. The species are still being propagated by the Orange County Insectary but it appears that our red scale is not a particularly favorable host for these beetles."

The *Azya* mentioned in Professor Smith's letter is the *Pentilia castanea* of the specialists of the Bureau of Entomology and Plant Quarantine.

To date we have no further information concerning developments in Florida.

No entomological explorer in foreign countries could wish for greater gratification than that experienced by the writer upon his return to Puerto Rico at the termination of investigations in Peru. On June 30, in company with K. A. Bartlett, of the Bureau of Entomology and Plant Quarantine, who received the shipments and made the original liberations of the predators, the writer collected the progeny of the two dominant species (*Cryptognatha nodiceps* and *Pentilia castanea*) which he had sent from Trinidad only five months earlier, for the purpose of further colonizations. Not only were these two species already well established in their new home, but they had multiplied so rapidly that it was possible to collect 332 adults in less than two hours. The feeling of satisfaction was heightened when, on July 16, the morning of his departure for Washington, the writer, again with Dr. Bartlett, found these two species 3 miles from the center of the original colony. The dispersion was in an easterly direction, towards the largest of the coconut groves on the island. Unfortunately, time was not available to continue the survey to determine the exact limits of dispersion.

Specimens collected in Puerto Rico and submitted to the experts of the Bureau for identification indicate the establishment of at least two other species of coccinellids sent from Trinidad in addition to those named.

One of the advantages of biological control work in tropical countries is that results become quickly known. In temperate regions the establishment of beneficial insects may remain in doubt for several years, sometimes a decade or more. On the other hand, in the Tropics, where shorter life cycles and continuous breeding are the rule, the success or failure of attempts at biological control by introduced species may be determined in a comparativly short time.

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